SR 108 MP 9.47 Kamilche Creek: Preliminary Hydraulic Design Report

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SR 108 Kamilche Creek – Remove Fish Barrier
MP 9.47 Kamilche Creek
Preliminary Hydraulic Design Report
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1.0 Introduction and Purpose

To comply with United States, et al vs. Washington, et al No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas (WRIAs) 1-23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the SR 108 crossing of Kamilche Creek at Mile Post (MP) 9.47. This existing structure on SR 108 has been identified as a fish barrier by Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (Site ID 997225) due to depth. Per the injunction, and in order of preference, fish passage should be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, or (c) use of the stream simulation methodology. WSDOT evaluated design options as defined in the injunction. Avoidance of the stream crossing was determined to not be viable given the location of the highway and the need to maintain this critical transportation corridor. WSDOT is proposing to replace the existing crossing structure with a structure designed using the bridge design methodology.

The structure is located in Mason County approximately 9.5 miles south and east of Shelton, WA in Water Resource Inventory Area (WRIA) 14.0022. The highway runs north-south at this location and the creek crosses the highway about 1,400 feet from the confluence with Skookum Creek. Kamilche Creek generally flows east to west beginning roughly two miles upstream of the SR 108 crossing. During a site visit conducted on August 23, 2019, the reach upstream of the culvert crossing was observed to have dense vegetation and evidence of incision. Portions of the stream appear to have been widened, caused by a wetland complex and potential beaver activity. See Figure 1 for the vicinity map.

The proposed project will replace the existing 72 foot long, 60-inch diameter corrugated metal culvert with a minimum 22 foot span structure to improve fish passage while providing a safe roadway for the traveling public. This proposed structure is designed to meet the requirements of the federal injunction utilizing the bridge design criteria outlined in the 2013 WDFW Water Crossing Design Guidelines (WCDG).

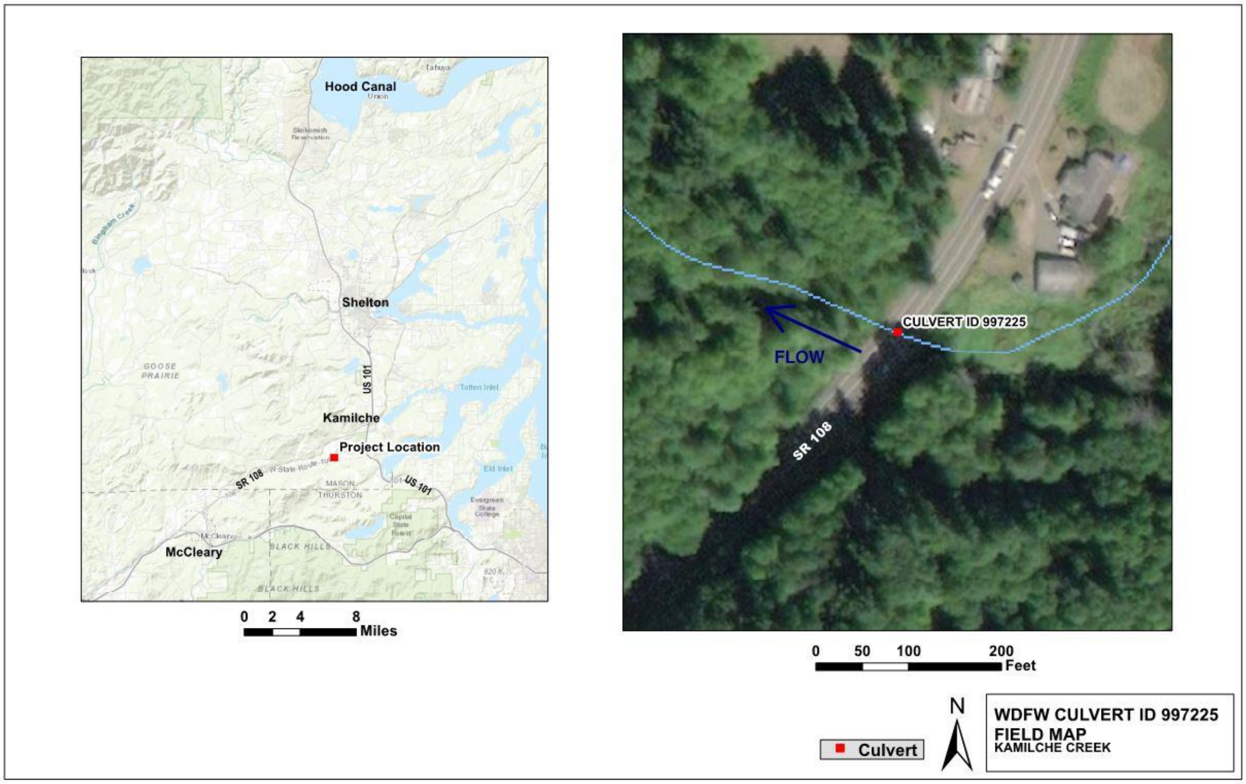

Figure 1 Vicinity map

2.0 Site Assessment

Osborn Consulting, Inc. (OCI) and HDR conducted a site visit on August 23, 2019 to visually assess the stream and collect information to support the design of the Kamilche Creek/SR 108 culvert crossing. OCI also conducted an independent site visit on August 29, 2019 to supplement prior field efforts. The team walked the stream from approximately 300 feet upstream of the inlet to approximately 300 feet downstream of the outlet of the existing 60-inch diameter corrugated metal culvert. The following provides a description of field observations moving from upstream to downstream.

The site reconnaissance starts approximately 300 feet upstream of the existing culvert inlet, where the stream flows through a large wetland complex heavily vegetated with canarygrass (Figure 2).

Figure 2 Wetland complex and typical, densely vegetated upstream channel

Downstream of the wetland area, the stream is backed up behind a mass of wood and sediment, potentially due to beaver activity, forming a pool approximately 150 feet upstream from the culvert inlet. Below the debris jam, the stream is incised and flows through a corridor that is densely vegetated with shrubs and mixed forested canopy. The incised stream flows into another pool just upstream of the culvert inlet (Figure 3); at this location an approximately 2-foot wide tributary flows into the pool from river left looking downstream (Figure 3). The streambed substrate upstream of the culvert inlet is dominated by fine silt and sand material with very few gravel and cobbles present.

Figure 3 Pool upstream of culvert inlet (left); corrugated metal culvert inlet (right)

Downstream of the culvert outlet, a pool has formed behind another accumulation of wood and sediment, potentially due to beaver activity (Figure 4). The stream flow is backed up and appears to be widened by the debris jam, which spans approximately ¾ of the stream channel. Approximately 80 feet downstream of the culvert outlet, an approximately 2-foot wide tributary enters the stream from river left looking downstream. The stream channel begins to narrow, and bank heights increase. The channel appeared to be moderately incised, and evidence of undercut banks and root scour was observed throughout the downstream reach.

Figure 4 Culvert outlet and pond downstream of culvert outlet

The reach downstream of the lower pool was determined to be the most representative of the natural channel. OCI measured three bankfull widths between approximately 50 feet downstream of the pool, and approximately 300 feet downstream of the culvert outlet, measuring 16 feet, 16 feet, and 15.3 feet (Figure 5).

Figure 5 Bankfull width measurements at two locations downstream of culvert crossing

3.0 Watershed Assessment

3.1 Watershed & Landcover

Kamilche Creek flows in a generally northwesterly direction and joins Skookum Creek approximately 1,400 feet downstream of the SR 108 culvert outlet. Skookum Creek drains into the Little Skookum Inlet near Kamilche, which flows into Totten Inlet and eventually into the Puget Sound. The drainage area to Kamilche Creek at the existing SR 108 culvert is approximately 1.82 square miles delineated based on LiDAR data using GIS ArcHydro tools (Figure 6). The maximum and mean basin elevations of 919 feet and 286 feet, respectively, based on the USGS StreamStats. The mean annual precipitation is 65.6

inches/year (PRISM). Overall, the basin land cover is approximately 65 percent forested with smaller areas of agricultural land north and south of SR 108 (USGS, 2019).

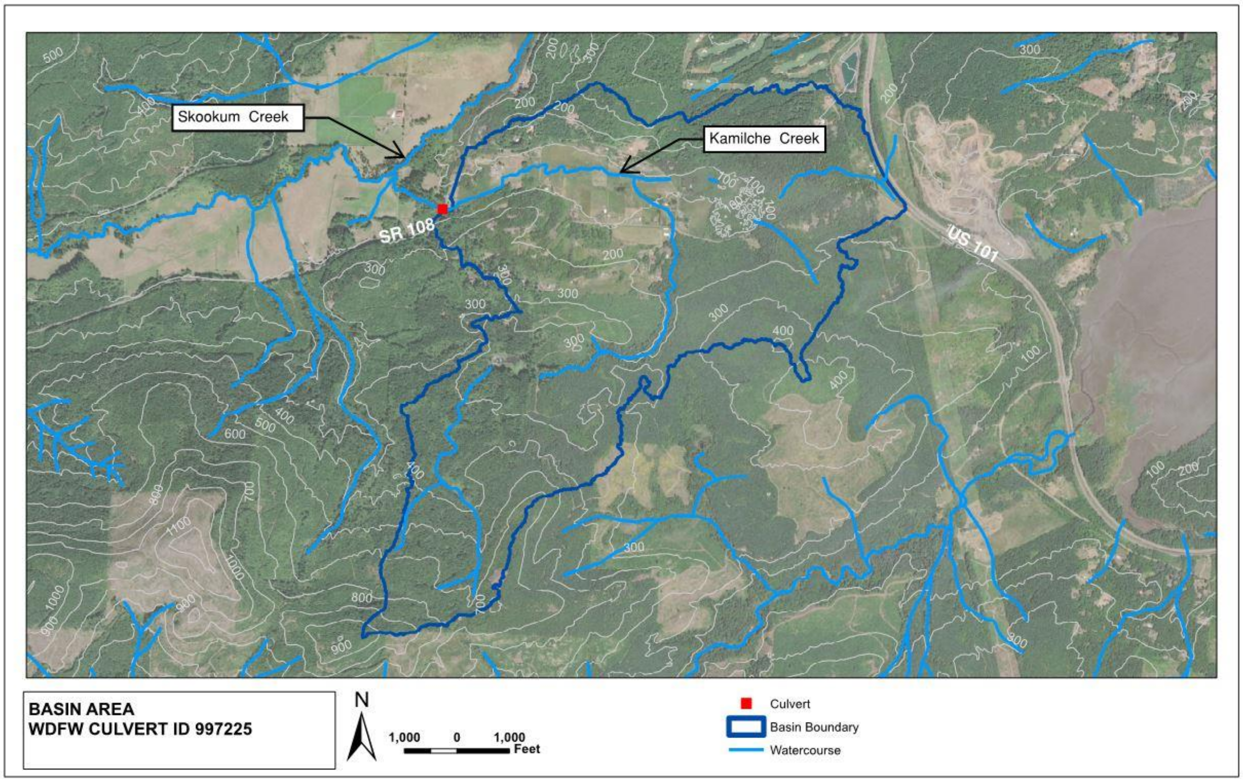

Figure 6 Basin boundary

3.2 Mapped Floodplains

The existing SR 108 culvert is not within a mapped floodplain based on FEMA Flood Rate Insurance Map (FIRM) 53045C0750E effective June 20, 2019 (shown in Figure 7). Approximately 1,000 downstream of the crossing, a Zone A floodplain has been mapped for Skookum Creek.

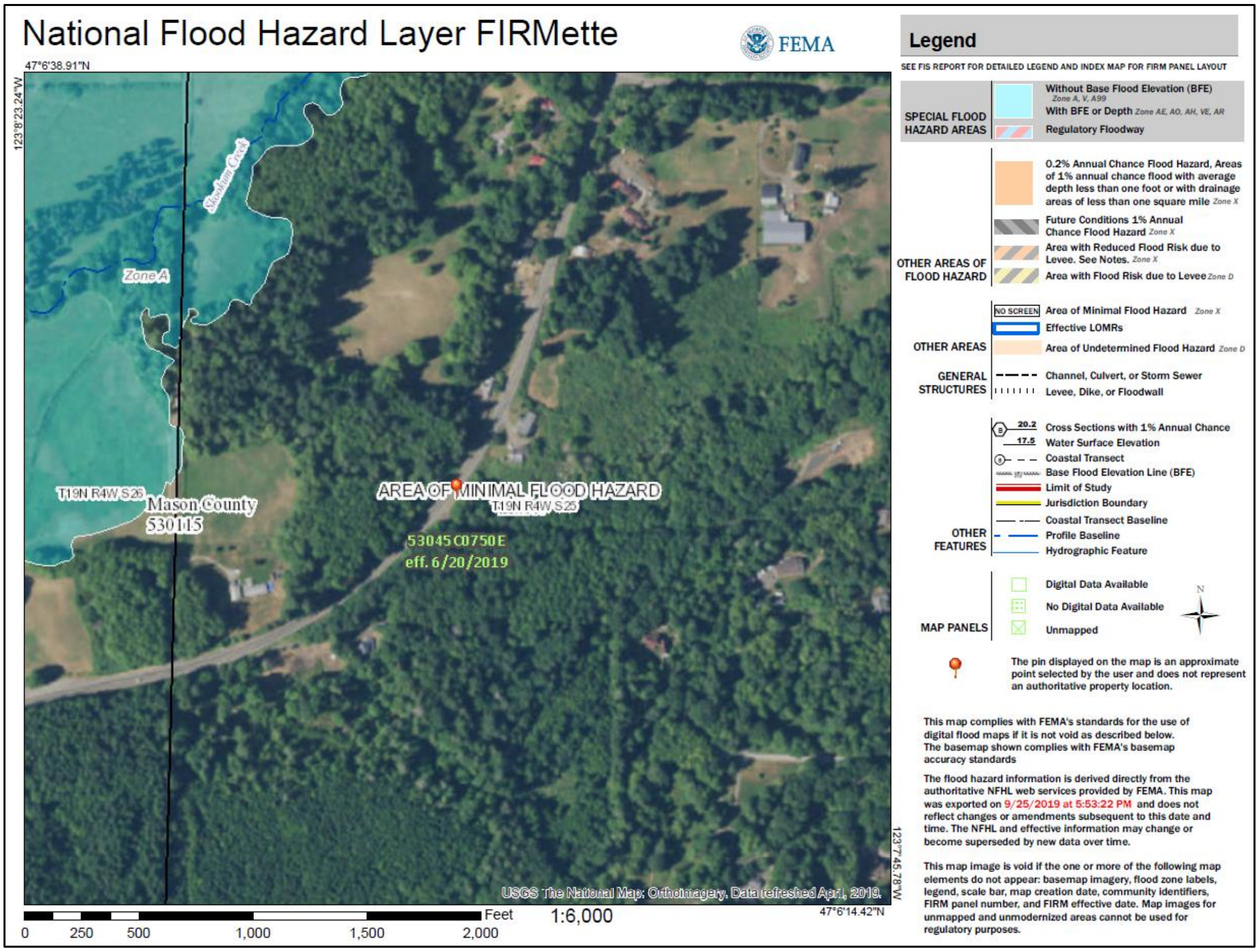

Figure 7 FEMA floodplain map (FIRM 53045C0750E)

3.3 Geology & Soils

The Kamilche Creek basin is underlain by deposits left by the most recent continental glacial recession event between 13,000 and 18,000 years ago. DNR classifications were used to characterize the geologic units within the Kamilche Creek drainage area (Figure 8). At the upper reaches of the basin, Crescent Formation basalt (Ev_c) is the primary geologic group, and Vashon Stade Till (Qgt) dominates the soil profile descending in elevation toward the Kamilche Valley floor. The buffer between the till and Little Skookum Valley consists of Vashon Stade proglacial and recessional outwash (Qgo). The Little Skookum Valley floor, which includes the mainstem of Kamilche Creek, and the wetland complex at the valley's upper end is comprised of Alluvium (Qa), which continue into the confluence with Skookum Creek. These geologic units are further described as follows:

> **(Ev_c) Crescent Formation basalt** – Tertiary igneous rock of lower to middle Eocene period; characterized by dark gray greenish tint, brown where weathered, reddish and variegated along altered contact zones.

> **(Qgt) Till, late Wisconsinan (Pleistocene epoch), Vashon Stade** – Continental glacial deposits of Fraser Glaciation; unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and

boulders deposited by glacial ice; typically gray and may contain interbedded stratified sand, silt, and gravel

(Qgo) Proglacial and recessional outwash, late Wisconsinan (Pleistocene epoch), Vashon Stade - Continental glacial deposits of Fraser Glaciation; poorly to moderately sorted, rounded gravel and sand with localized coarser- and finer-grained constituents; typically shades of gray where fresh or brown where stained

(Qa) Alluvium – Holocene nonglacial deposits; characterized by sorted combinations of silt, sand, and gravel deposited in streambeds and alluvial fans; locally may include alpine drift, peat, lacustrine, or landslide deposits.

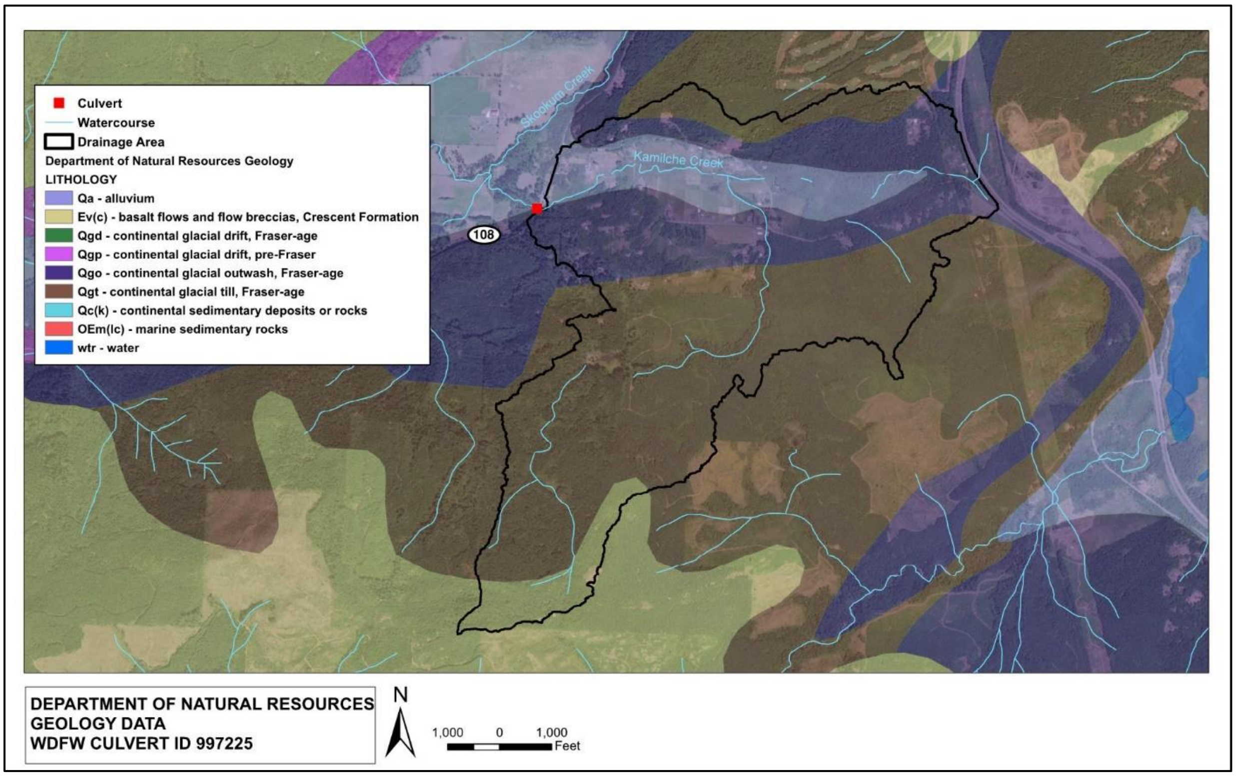

Figure 8 Geologic Map for Kamilche Creek Drainage Basin (WA DNR Geologic Units 100k)

Soils (shown in Figure 9) within the basin primarily include gravelly loam, gravelly sandy loam, silt loam, loam, unweathered bedrock, Tebo soil material, and Tebo-Shelton complex. Tebo soil material is described as till derived from basalt consisting of silt loam and gravelly clay loam on steep slopes. Shelton soil material is described as basal till with volcanic ash consisting of very gravelly medial loam to very gravelly sandy loam. The hydrologic soil groups (HSG) of the soils within the basin are approximately 60% A, 22% B, 8%C, and 10% D or underlain with D soils. These soils range from well-drained with high infiltration rates (HSG A) to poorly drained, saturated soils (HSG D).

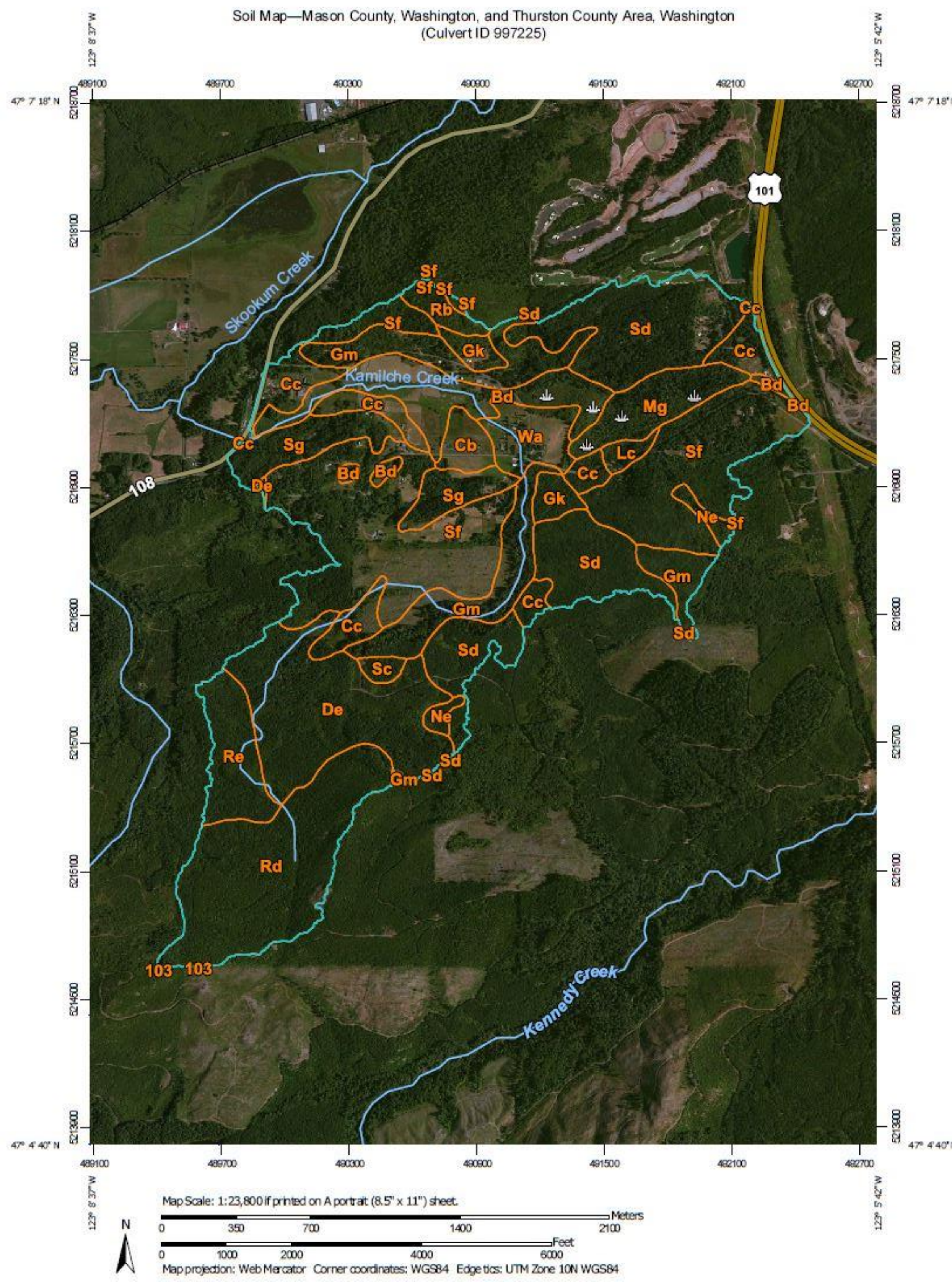

Figure 9 Web Soil Survey Map for Kamilche Creek Drainage Basin (USDA Web Soil Survey, 2019)

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Bd	Bellingham silt loam, 0 to 3 percent slopes	71.7	6.1%
Cb	Cloquallum silt loam, 0 to 5 percent slopes	14.4	1.2%
Cc	Cloquallum silt loam, 5 to 15 percent slopes	70.1	6.0%
De	Delphi gravelly loam, 5 to 15 percent slopes	125.3	10.7%
Gk	Grove gravelly sandy loam, 5 to 15 percent slopes	18.6	1.6%
Gm	Grove gravelly sandy loam, 15 to 30 percent slopes	108.8	9.3%
Lc	Lystair loamy sand, 5 to 15 percent slopes	6.6	0.6%
Mg	Mukilteo peat, 0 to 2 percent slopes	38.1	3.3%
Ne	Norma silt loam, 0 to 3 percent slopes	10.2	0.9%
Rb	Rough broken land	11.3	1.0%
Rd	Rough mountainous land, Tebo soil material	134.0	11.5%
Re	Rough mountainous land, Tebo-Shelton complex	41.0	3.5%
Sc	Semiahmoo muck shallow, 2 to 10 percent slopes	5.3	0.5%
Sd	Shelton gravelly loam, 5 to 15 percent slopes	164.6	14.1%
Sf	Shelton gravelly sandy loam, 5 to 15 percent slopes	265.1	22.7%
Sg	Shelton gravelly sandy loam, 15 to 30 percent slopes	53.3	4.6%
Wa	Wadell gravelly loam, 0 to 5 percent slopes	28.9	2.5%
Subtotals for Soil Survey Area		**1,167.1**	**100.0%**
Totals for Area of Interest		**1,167.2**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
103	Schneider very gravelly loam, 40 to 65 percent slopes	0.1	0.0%
Subtotals for Soil Survey Area		**0.1**	**0.0%**
Totals for Area of Interest		**1,167.2**	**100.0%**

USDA **Natural Resources Conservation Service** Web Soil Survey National Cooperative Soil Survey 9/30/2019 Page 3 of 3

Figure 10 Web Soil Survey Map Legend for Kamilche Creek Drainage Basin (USDA Web Soil Survey, 2019)

Kamilche Creek drains a flat to moderately sloped basin before it reaches the edge of the Skookum Creek floodplain on the west side of SR 108. Of the 1.82 square mile area that Kamilche Creek drains upstream of the SR 108 crossing, the mean basin slope is 12 percent as reported by StreamStats. Approximately 0.61 percent of the basin area has a slope steeper than 30 percent. The basin elevations range from 66 feet at the SR 108 culvert crossing to 919 feet at the south and southwest edges of the drainage basin (StreamStats).

3.4 Geomorphology

3.4.1 Channel Geometry

Channel bed features include pools, a wetland complex, and an incised stream channel upstream of the culvert inlet with depth of incision ranging from 2 to 3 feet. Potential beaver activity appears to have contributed to the formation of both the pool and the wetland complex within the stream corridor upstream of the SR 108 crossing. A tributary flows into the channel from river left looking downstream, just upstream of the SR 108 crossing. The tributary contributes to the pool that has formed just upstream of the culvert inlet.

Downstream of the culvert outlet, the channel was observed to be artificially widened upstream of a debris jam, potentially due to further beaver activity, which spans approximately three-quarters of the stream channel. Below the pool, the stream was observed to be slightly incised with evidence of undercut banks (Figure 11). Approximately 80 feet downstream of the culvert outlet, an approximately 2-foot wide tributary enters the stream from river left looking downstream. Several mid-channel sediment bars were encountered within the reach.

Figure 11 Channel upstream of culvert inlet (left) and channel downstream of culvert outlet (right)

The January 2003 WDFW field report notes a low channel gradient (0 to 1%) with a minimal amount of gravel in the upstream reach and several beaver dams, some also associated with debris jams. The stream channel downstream of the culvert crossing was determined to be the most representative of the natural channel observed during the site visit. Bankfull widths were measured to be 16 feet, 16 feet, and 15.3 feet, and were taken at the downstream end of the site reconnaissance area, below the downstream pool. Bank heights of the stream channel downstream of the pool varied from approximately 2.5 to 3 feet. The January 2003 WDFW field report notes a low gradient (0 to 1%) and scattered tailouts with good gravel in the downstream reach.

A WDFW regression bankfull width is 16.0 feet, based on basin area (1.82 square miles) and annual precipitation (65.6 inches per year).

A long channel profile was developed from the 2019 survey data and 2005 Puget Sound Lowlands LiDAR data (Figure 12). Upstream of the project area, the average reach slope is 0.4 percent. Within the detailed survey, the reach slope increases to an average of 0.8 percent. The reach downstream of the survey is less steep, with an average slope of 0.2 percent.

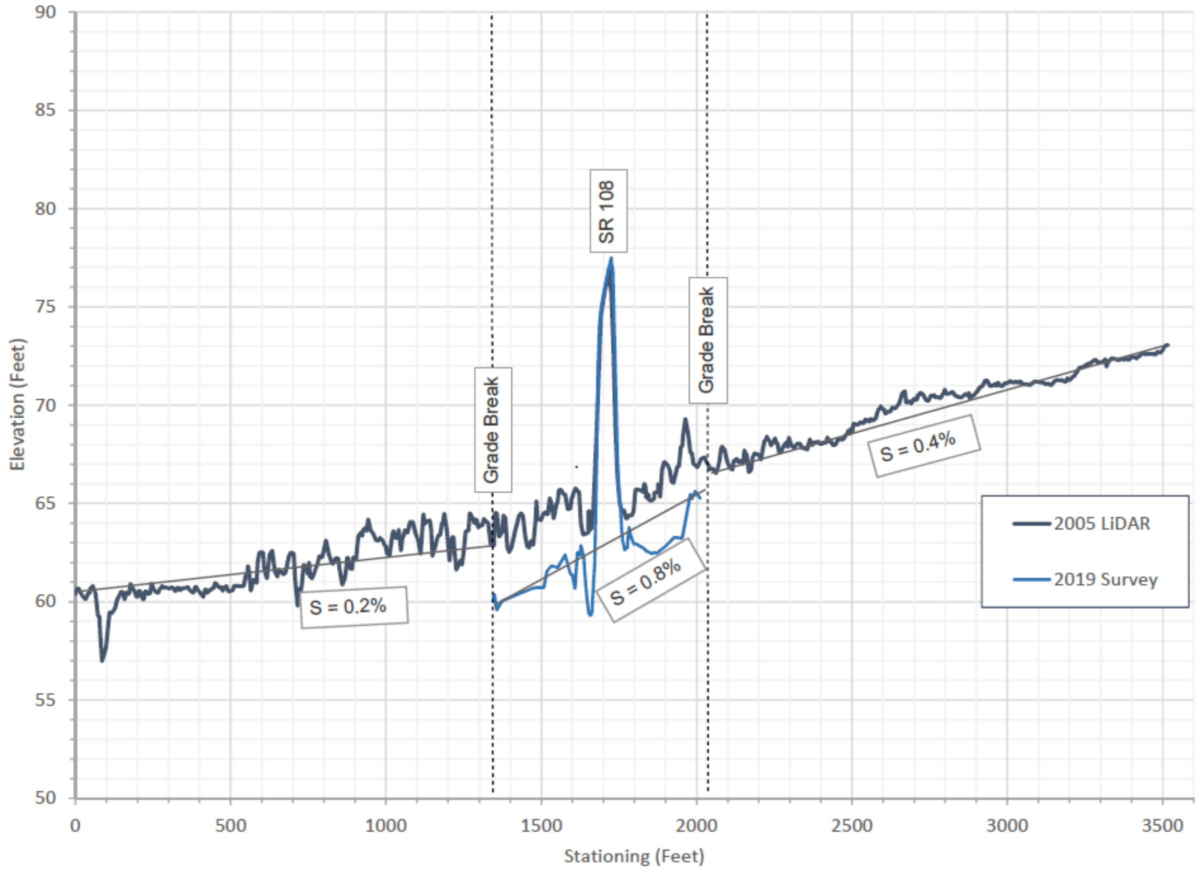

Figure 12 Long profile of Kamilche Creek near SR 108 crossing

3.4.2 Potential for Aggradation, Incision and Headcutting

The January 2003 WDFW field report notes a consistent low gradient (0 to 1%) throughout the up and downstream reach. The wetland and debris jams both upstream and downstream of the culvert crossing, cause significant accumulation of wood and sediment, contributing to further artificial channel widening. Upstream, the channel is dominated by fine streambed material. Downstream, the streambed substrate was observed to be composed primarily of fines, with few cobbles present. The existing dam features could continue to deprive downstream reaches of migrating sediment. No evidence of headcutting or discontinuity in the channel grade was observed during the site visit except for at the culvert outlet. The culvert is currently perched, and if replaced could increase the potential for a small headcut to develop upstream of the crossing.

3.4.3 Floodplain Flow Paths

Upstream of the crossing the left bank is confined by a steep hillside, while the right bank is shallow and appear accessible to low frequency flood events. Downstream of the crossing the right bank is higher than the left and appears to have limited floodplain conveyance. The left bank is low with several small tributaries flowing through the left floodplain.

3.4.4 Channel Migration

The channel is not expected to expand nor move around within its floodplain. The dense vegetation lining the stream banks throughout the observed reach and channel incision suggests the stream has a low potential for channel migration within its floodplain. The primary landcover in the basin is forested, and flows are not expected to change significantly if the land cover remains undisturbed. There were several areas where evidence of undercut banks was observed along the downstream reach.

3.4.5 Existing LWM and Potential for Recruitment

The upstream reach of Kamilche Creek does not appear to have adequate channel width to transport LWM from upstream reaches. Therefore, all potential for LWM recruitment is from localized recruitment such as deadfall, windfall, and bank erosion. The riparian corridor along the upstream reach is dominated by reed canarygrass, shrubs and small trees. The reach does not contain a significant number of large trees, which limits the potential for wood recruitment. Minimal wood accumulations were observed in the upstream reach, however, those observed were likely due to localized beaver activity.

Downstream of the culvert crossing, wood accumulation appeared to be more common than in the upstream reach. The downstream riparian corridor was vegetated shrubs and a mixture of trees. However, the corridor appeared to contain more large trees than in the upstream reach, as well as evidence of undercut banks, which offers potential for wood recruitment. The January 2003 WDFW Report supports the assessed potential for recruitment of Large Woody Material (LWM).

3.4.6 Sediment Size Distribution

The streambed substrate upstream of the culvert inlet appeared to be dominated by fine silt and sand material with minimal gravel and cobbles present. Downstream, the streambed substrate contains more small gravels and cobbles, with several sediment bars observed along the reach. Streambed boulders were not observed within the limits of the site visit for this stream. Three pebble counts were taken in the downstream reach during the site reconnaissance and the cumulative results of the sediment size distribution are compiled in the graph (Figure 13) and table below (Table 1). Figure 14 includes a picture of the typical substrate size observed.

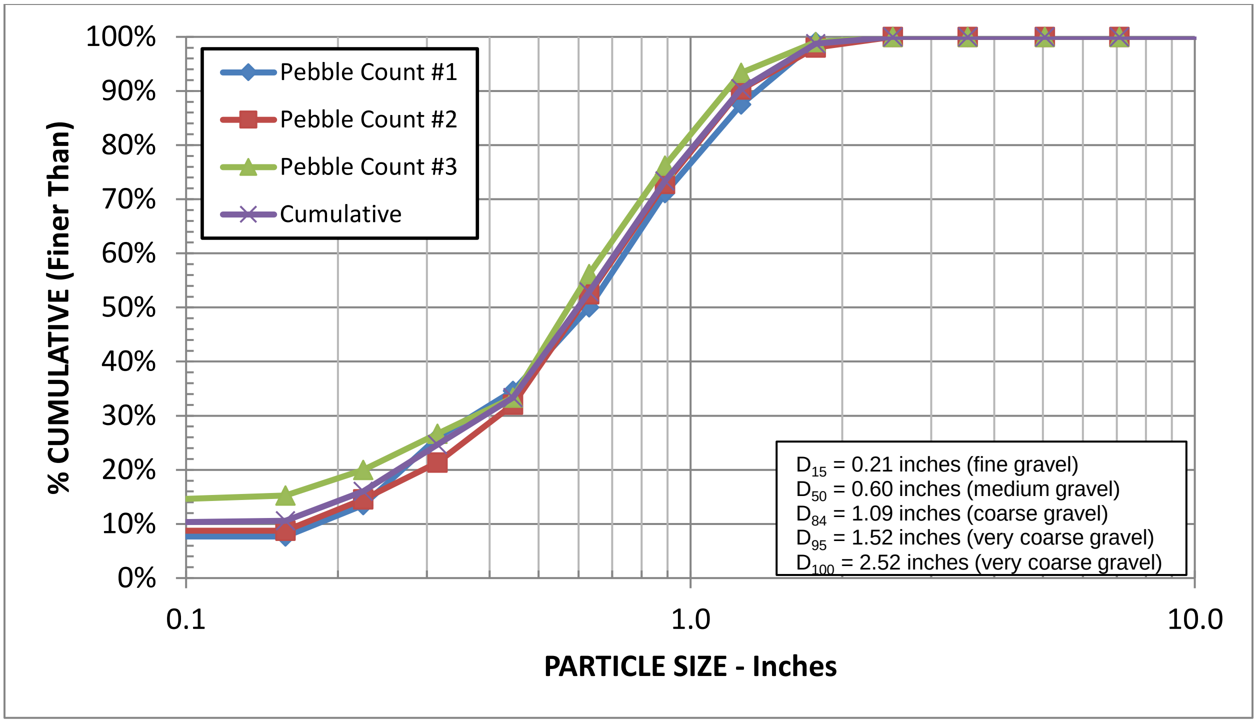

Figure 13 Sediment size distribution

Table 1 Sediment properties downstream of SR 108 Crossing

Particle	Diameter (in)
D_{15}	0.21
D_{35}	0.45
D_{50}	0.60
D_{84}	1.09
D_{95}	1.52
D_{100}	2.52

Figure 14 Pebble counts in the downstream reach

3.5 Groundwater

The Washington State Department of Ecology well log database, EIM database, and the USGS NWIS were queried for groundwater level data. One water well (Well Report ID AFF 214) was identified approximately 6300 feet west of the crossing. It appears that the well installed in 2000 is for domestic use and serves the residential property. The static water level was found to be 31 feet below the top of the well.

Ground water appears to be close to the surface directly upstream of the site. Several seeps were observed along the left bank hillside upstream of the crossing.

4.0 Fish Resources and Site Habitat Assessment

4.1 Fish Use

Skookum Creek and its tributaries including the portion of Kamilche Creek that is located in the project site support the occurrence of fall-run coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), winter-run steelhead (*Oncorhynchus mykiss*) and coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) (WDFW PHS data 2019a; WDFW Salmonscape 2019b; Streamnet 2019). Of these species, winter steelhead that inhabit the watershed are part of the Puget Sound Distinct Population Segment (DPS) and are federally listed as threatened under the Endangered Species Act (ESA) of 1973. Besides salmonids, several additional fish species, including sculpin and lamprey, also inhabit the watershed. Table 2 provides a list of native fish potentially found in Skookum Creek and its tributaries. There were shallow, low flows in the creek at the time of the field visit in August 2019, and no fish were observed.

Table 2 Native fish species potentially found

Species	Source (Assumed, Mapped, or Documented)	Pre-Existing Fish Use Surveys (spawner surveys or other biological observations)	Life History Present (Egg, Juvenile, Adult)	Limiting Habitat Factors	Stock Status and/or ESA Listing
Coho (*Onchorhynchus kisutch*)	Documented	Statewide Integrated Fish Distribution (SwIFD), Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Fall Chum (*Onchorhynchus keta*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Winter Steelhead (*Onchoryhnchus mykiss*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Federally Threatened
Coastal Cutthroat (*Onchoryhnchus clarkii clarkii*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Sculpin (*Cottus*)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Lamprey (Lampreta)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted

4.2 Existing Habitat

Skookum Creek is a significant watershed in South Puget Sound, with numerous tributaries providing habitat for salmonids. Land use at higher elevations is predominately timber production, with livestock and pasture/hayfields in the mid and lower valleys. The Skookum Creek watershed provides spawning and rearing habitat for coho, chum, steelhead, and cutthroat trout throughout the mainstem and accessible reaches of its tributaries. These anadromous species are part of Puget Sound stocks and access Skookum Creek through the Little Skookum Inlet off Totten Inlet in South Puget Sound.

In addition to fish passage barriers in the upper watershed, the most significant biological impairments are habitat diversity and quantity, sediment load and transport, and summer water temperatures. Kamilche Creek (also referred to as Hurley Waldrip Creek) is a right bank tributary to Skookum Creek that provides rearing and migratory habitat, as well as potential spawning habitat for salmonids and other fish species.

4.2.1 Immediate Crossing

The current crossing is a partial barrier to upstream fish passage due to low flow depth constraints; in 2005, it was reported as 67% passable by WDFW. Coho, chum, and steelhead are not known to migrate above the culvert during low flows. The barrier condition of the culvert is assumed to be impeding both adult and juvenile salmon use of reaches upstream.

4.2.2 Quality Within Reach

Downstream of the SR 108 culvert crossing, Kamilche Creek flows through a large, deep pool at the culvert outlet, and through a mixed canopy forested riparian area containing alder (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*), with some conifers including Douglas fir (*Pseudotsuga menziesii*) and western red cedars (*Thuja plicata*). There is a dense shrub understory with native and non-native species including salmonberry (*Rubus spectabilis*), vine maple (*Acer circinatum*), and Himalayan blackberry (*Rubus armeniacus*). The mature forest and shrub cover provides good shading, nutrient inputs, and some potential large woody material (LWM) recruitment. A few small pieces of LWM were observed in the reach, but large structural pieces were lacking.

Downstream of the culvert is a shallow, low gradient channel with some pool-riffle habitat. The substrate is a mix of gravel and fines. This reach provides good rearing habitat, particularly at higher flows, but spawning habitat is lacking in the study reach. The confluence with Skookum Creek is located approximately 0.25 miles downstream of the culvert crossing. Skookum Creek continues for approximately 3.7 miles to where it enters Little Skookum Inlet, and on to Totten Inlet off Puget Sound.

Upstream of the SR 108 culvert crossing, the Kamilche Creek flows through a large wetland area on the right bank with an open reed canarygrass field. The left bank has a steep upland slope with mature forest cover comprised of fir, cedar, alder, and big leaf maple.

There is a large, shallow pool at the culvert inlet, with deposition of fine sediment. The stream channel upstream is very low gradient and the bed is comprised of silt and is choked with reed canarygrass in some locations. The channel becomes more defined near the upstream end of the study reach, but the substrate remains dominated by fines and the stream is heavily overgrown with a shrub layer of nettle, vine maple, alders, and willow. Habitat in this reach is poor due to low flows and a substrate composed predominantly of fines. During seasonal higher flows this reach could provide rearing habitat for juveniles, but spawning habitat is not present in the study reach.

4.2.3 Length of Potential Gain

In July of 2003, WDFW surveyed 1.78 miles (9,406 feet) of Kamilche Creek upstream of the project site. The upstream surveyed reach was documented as providing 0.1 acre of potential spawning habitat, and 1.4 acres of rearing habitat (WDFW fish passage report 997225).

4.2.4 Other Barriers in System

There are 2 partial passage barriers mapped in Kamilche Creek at culverts under West Hurley Waldrip Road, upstream of the project reach. The current conditions, including the project crossing, block fish passage and prevent use of this section of the tributary, and disrupt sediment and debris transport downstream.

Downstream of the crossing under SR 108, Kamilche Creek flows roughly northward for approximately 0.25 miles, and enters the right bank of Skookum Creek. There are no barriers mapped downstream of the project crossing. Skookum Creek then flows roughly eastward and crosses under SR 108 and US 101 before entering Little Skookum Inlet. These crossings are bridges; there are no fish passage barriers in Skookum Creek downstream of the project crossing.

Figure 15 presents a map of Kamilche Creek where it joins Skookum Creek north of the project culvert, and the fish passage features that were documented by WDFW during their fish passage inventory and habitat survey.

4.2.5 Other Restoration Efforts in System

Commercial timberlands dominate the headwaters and upper watershed, while agricultural pasturelands, rural residential and urban development make up the majority of the valley floor through the lowlands.

The Squaxin Island Tribe owns portions of land in the lower reaches of Skookum Creek and its tributaries as it runs through the reservation. The Tribe, along with conservation groups have several completed and ongoing restoration and preservation projects in the Skookum Creek watershed. Tribal restoration projects in the watershed have improved freshwater habitat for salmonids, particularly for the coho run. Where Skookum Creek runs through Tribal property, the Squaxin Island Tribe has set aside 150-foot buffers on each side of the creek to protect ecological functions, and has begun replanting efforts.

The Tribe has also worked with the South Puget Sound Salmon Enhancement Group to dig out the steep, eroded banks of the lower creek. Instead of the near vertical 10-foot wall that previously existed, the stream bank is now a gentle slope and creates floodplain connectivity. Additionally, the partners are building logjams to recreate natural conditions of in-stream habitat to help create pools where adult salmon can rest while migrating upstream and rearing juveniles can find refuge.

Work has been undertaken to place additional wood in the tributaries, with substantial LWM and key pieces being added to Reitdorf Creek, a left-bank tributary to Skookum Creek, in 2002 with the use of helicopters. McDonald Creek is the focus of two proposed Family Forest Fish Passage Program projects, each removing previous partial barriers upstream of the SR 108 crossing.

The Washington Wildlife and Recreation Coalition is working in partnership with the Squaxin Island Tribe to help acquire and permanently protect 158 acres of wetlands and shorelines along Skookum Creek, using grant funding for the Skookum Valley Wetland Acquisition. The Squaxin Island Tribe’s plans to buy up to 614 acres in the Skookum Valley, depending on landowners’ willingness. This project will protect more than 4 miles of Skookum Creek and an additional 4.4 miles of tributaries, as well as a number of wetlands, stream banks, and forests.

Though there have been restoration efforts for Skookum Creek and its tributaries, there is no known restoration in the watershed for this Unnamed Tributary.

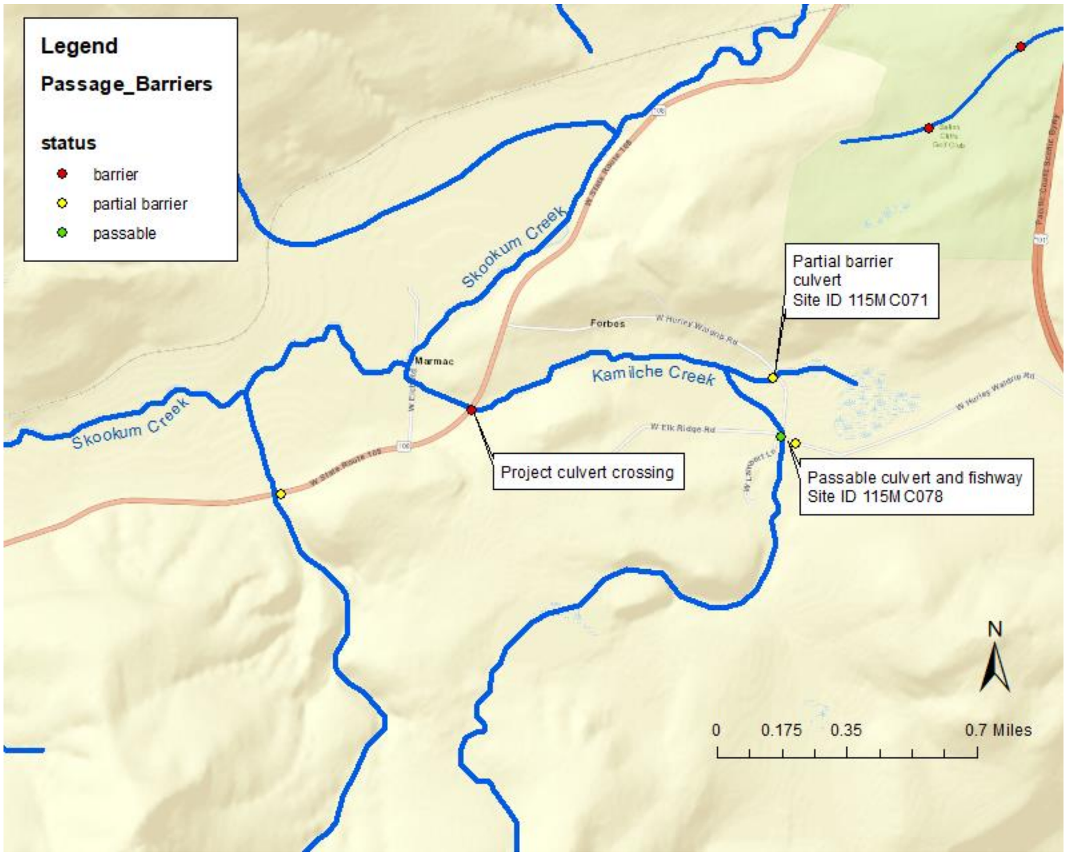

Figure 15 Fish passage features located on Kamilche Creek

5.0 Reference Reach Selection

During the August 23, 2019 site visit, the field team observed approximately 300 feet upstream and 300 feet downstream of the Kamilche Creek culvert crossing at SR 108. A reference reach was selected downstream of the crossing between bankfull width 1 (BFW 1) and bankfull width 2 (BFW 2), downstream of the scour pool that currently exists at the culvert outlet. This reach was deemed the most representative natural stream reach and is shown in Figure 16.

The upstream reach is incised and densely vegetated with tall grasses and shrubs. The upstream reach flows from a wetland complex and contains accumulations of woody debris and sediment, likely due to beaver activity, causing the stream to artificially widen and form pools. Additionally, a tributary flows into the channel just upstream of the culvert inlet. Due to these conditions, the upstream reach was determined to not be representative of the natural stream channel, and similarly not representative of a desirable stream channel to replicate when designing the stream crossing at this location.

Similar conditions to the upstream reach were observed in the downstream reach. The stream is artificially widened, forming a pool, due to a debris and sediment jam spanning approximately three-quarters of the stream channel width. Below the debris jam, the stream is slightly incised, with bank heights measuring approximately 2.5 to 3 feet. Evidence of undercut banks and several mid-channel sediment bars were observed. Dense vegetation dominated the downstream reach, and potential was noted for wood recruitment from trees along the banks. The downstream reach was determined to be the most representative of the natural channel, therefore bankfull widths and the pebble counts were conducted within the reach at locations shown in Figure 16. The downstream reach is the most representative reach identified during this site visit and is adequate to use for modeling a design condition for the Kamilche Creek/SR 108 culvert crossing improvements.

During the stakeholder site visit with WDFW, it was agreed upon to average the three previously collected bankfull widths and one additional bankfull width (16.5 feet) collected upstream. This additional bankfull width was collected upstream, approximately 15 feet downstream from the beaver dam, during the stakeholder site visit. Averaging these four bankfull widths results in a design bankfull width of 16 feet.

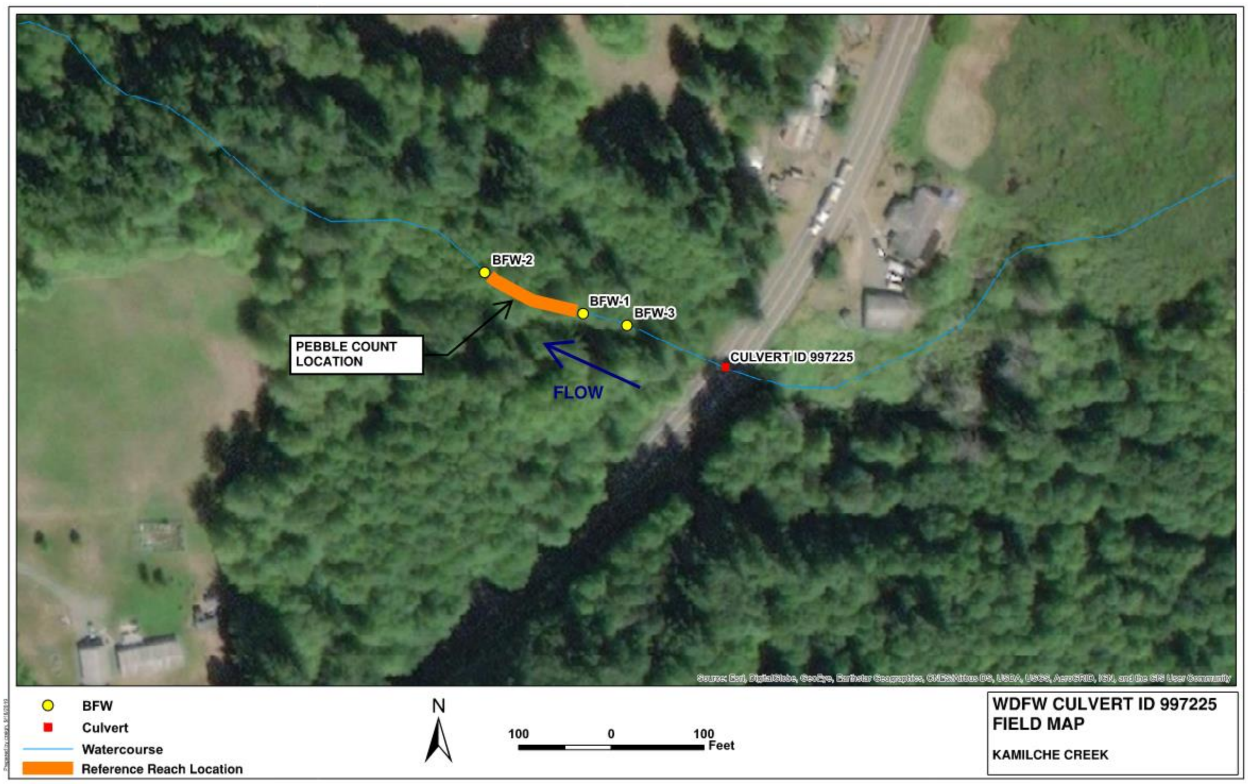

Figure 16 Bankfull width and pebble count measurement locations

6.0 Hydrology and Peak Flow Estimates

Due to lack of stream flow data on Kamilche Creek, peak flow estimates for Kamilche Creek were obtained from the USGS Regression Equation (Mastin, et al., 2016). Kamilche Creek has a basin area of 1.82 square miles and a mean annual precipitation within the basin of 65.6 inches (PRISM, 2019). Table 3 shows the calculated peak flows for Kamilche Creek at SR 108.

Table 3 Peak flows, Standard Error of Prediction and Prediction Intervals (at a 90% confidence interval) for Kamilche Creek at SR 108

Mean Recurrence Interval (MRI)	Kamilche Creek at SR 108 (cfs)	Standard Error of Prediction	Prediction Interval (lower)	Prediction Interval (upper)
2	76.2	43.2	38.5	151
5	118	44.4	58.3	239
10	147	45.6	71.8	301
25	183	48.1	85.8	391
50	209	50.5	95.1	460
100	238	51.8	106	533
200	266	54.2	114	619
500	305	57.7	126	741

7.0 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 108 Kamilche Creek crossing was performed using Bureau of Reclamation's SRH-2D Version 3.2.0 (USBR, 2017) computer program, a two-dimensional hydraulic and sediment transport model. It includes the ability to model dynamic interactions between the stream channel and overbanks, roadway overtopping, culverts, and the influence of bridge decks on bridge backwater. Pre- and post-processing of the model was completed using SMS Version 13.0.8 (Aquaveo, 2018). Appendix A contains detailed output from the hydraulic modeling effort.

Two scenarios were analyzed for determining stream characteristics for Kamilche Creek with the SRH-2D models: 1) existing conditions with the 60-inch diameter corrugated metal culvert and 2) future conditions with the proposed 22-foot hydraulic opening.

7.1 Model Development

7.1.1 Topography

Detailed channel geometry data in the model was obtained from the MicroStation and InRoads files, which were developed from topographic surveys performed by Lin & Associate surveyors. Additional topography in the floodplains was supplemented with LiDAR data by Lin & Associate surveyors. Proposed channel geometry was developed from the proposed grading surface created by HDR Engineering, Inc.

7.1.2 Model Extent and Computational Mesh

The hydraulic model upstream and downstream extents are consistent with the detailed survey boundary, approximately 225 feet upstream of the existing culvert outlet and 290 feet downstream of the existing culvert outlet, measured along the channel centerline. The left and right banks were supplemented with LiDAR data to capture the full extents of floodplain over the range of modeled flows (Figure 17). The computational mesh elements was a combination of patched and paved (triangular) elements, with finer resolution in the channel and larger elements in the floodplain.

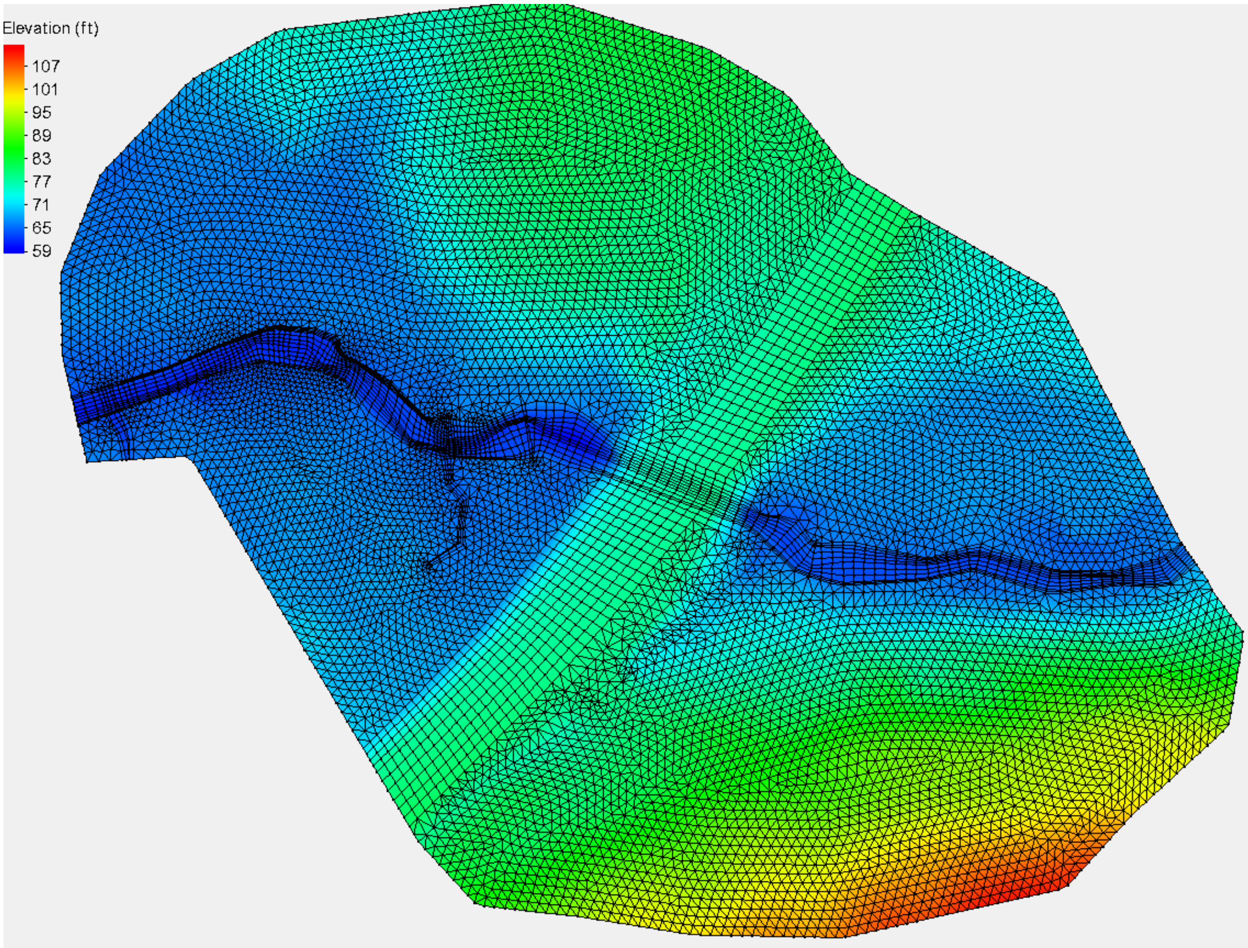

Figure 17 Existing computational mesh with underlying terrain

7.1.3 Roughness

Manning's n values were estimated based of site observations, aerial photography and standard engineering values (Chow, 1959) and are summarized below (Table 4). Roughness in the overbanks represents dense vegetation and undergrowth associated with the grasses, shrubs and trees in the riparian areas.

Table 4 Summary of roughness coefficients

Land Cover	Manning's Roughness Coefficient
Channel	0.04
Road	0.02
Forested Floodplain	0.10
Grassy Floodplain	0.05

7.1.4 Boundary Conditions

Model simulations were performed using multiple quasi-steady state discharges ranging from the 2-year to 500-year peak flow events summarized described in Section 6.0. External boundary conditions were applied at the upstream and downstream extents of the model and remained the same between the existing and proposed conditions runs. A constant flow rate was specified at the upstream external boundary condition, while a normal depth rating curve was specified at the downstream boundary. The downstream normal depth boundary condition rating curve was developed within SMS using the existing terrain, assuming a downstream slope of 1% as measured from the survey and a composite roughness of 0.04 for all runs except the 500-year flow event, which used a composite roughness of 0.055 (weighted average of channel and forested floodplain roughness based on wetted area of cross section at the 500-year event).

A HY-8 internal boundary condition was specified in the existing conditions model to represent the existing circular corrugated metal culvert crossing. The existing crossing was modeled as a 5-foot diameter circular pipe within HY-8. A manning's roughness of 0.024 was assigned to the culvert. The culvert was assumed to be unobstructed and free from any stream material within the barrel.

7.1.5 Model Geometries

Two geometries were developed for simulation with SRH-2D, representing existing and proposed conditions. The existing conditions includes the existing circular metal culvert crossing of SR 108. The existing condition geometry was modified to develop the proposed conditions by removing the existing culvert and associated internal boundary conditions. Additionally, the terrain was updated to reflect the proposed grading and 22-foot span hydraulic opening. The walls of the proposed structure were modeled as voids in the computational mesh. Model geometry outside of the proposed improvements are the same for the proposed conditions as the existing condition.

7.2 Model Results

Hydraulic results were summarized and compared at common locations between the existing and proposed simulations (Figure 18). The upstream cross section is located at approximate station 4+31 and is at the inlet of the proposed hydraulic opening. Downstream the cross section was located at station 2+17, 110 feet downstream of the existing culvert outlet. Hydraulic variables reported include water surface elevation, depth, velocity and shear stress at each cross section. Appendix A contains the more detailed hydraulic output.

In addition to cross section results, results were summarized along the channel longitudinal profile. Both existing and proposed condition hydraulic results were reported using the same alignment (Figure 19).

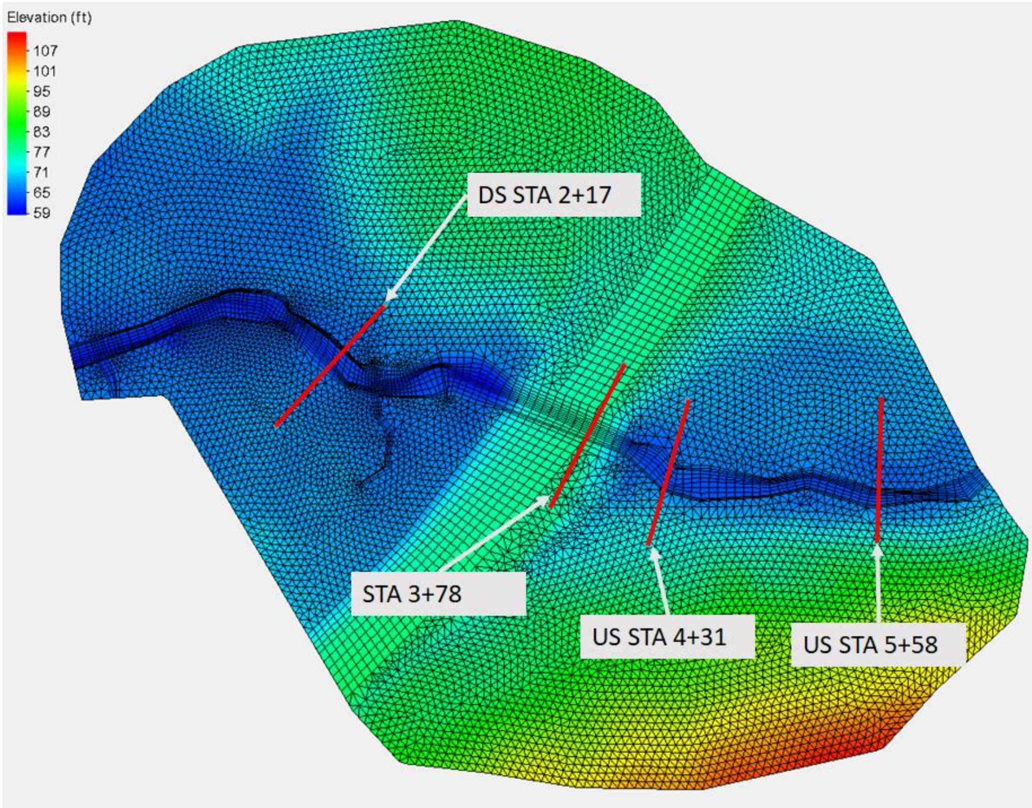

Figure 18 Locations of cross sections used for results reporting

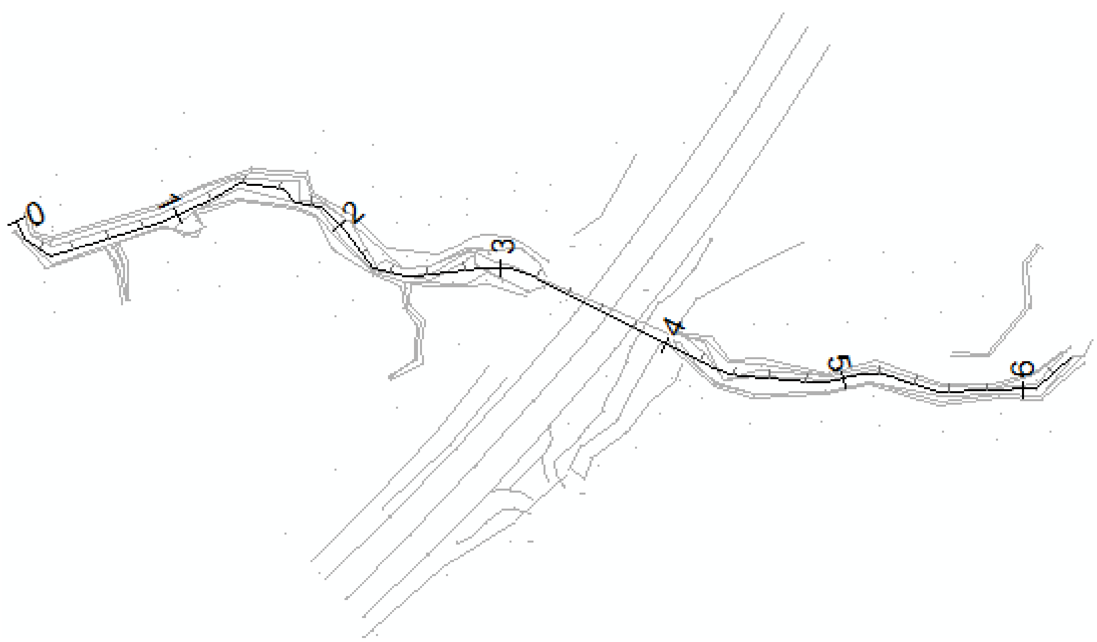

Figure 19 Longitudinal profile stationing for existing and proposed conditions

7.2.1 Existing conditions – 5 Foot Diameter CMP Culvert

Existing conditions hydraulic results are summarized for the upstream and downstream cross sections in Table 5 below. Under existing conditions, the culvert causes a backwater upstream for the range of flows simulated (Figure 20). Pressure flow conditions were first observed during the 25-year event simulation. The existing roadway was overtopped by the 500-year event.

As a result of the backwater, the upstream depths are greater than the downstream reach. In addition, the upstream shear and velocities are lower than their downstream counter parts. Upstream channel velocities varied from 0.44 ft/sec during the 500-year event to 1.23 ft/sec during the 2-year event. At the downstream cross section velocities ranged from 3.55 ft/sec at the 2-year event to 4.33 ft/sec at the 100-year event. Shear varied from 0 lb/ft^2 to 0.05 lb/ft^2 at the upstream cross section during the 500-year event and the 2-year event, respectively. Larger shear values were present at the downstream cross section, ranging from 0.54 lb/ft^2 during the 500-year event to 0.65 lb/ft^2 at the 100-year event. When looking at the entire model domain, the largest velocities occurred at the culvert outlet and the channel downstream of the culvert (Figure 21).

Table 5 Hydraulic results for existing conditions within main channel

Hydraulic Parameter	Cross Section	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	XS 2+17	63.81	65.06	65.29	65.51	66.06
	XS 4+31	66.98	71.21	72.79	74.39	77.54
	XS 5+58	67.02	71.22	72.79	74.39	77.54
Max Depth (ft)	XS 2+17	1.79	3.04	3.27	3.50	4.05
	XS 4+31	4.11	8.33	9.91	11.51	14.66
	XS 5+58	4.14	8.33	9.90	11.50	14.65
Average Velocity (ft/s)	XS 2+17	3.55	3.99	4.22	4.37	4.39
	XS 4+31	0.98	0.55	0.48	0.45	0.44
	XS 5+58	1.23	0.62	0.54	0.49	0.44
Average Shear (lb/sq-ft))	XS 2+17	0.56	0.60	0.63	0.67	0.64
	XS 4+31	0.03	0.01	0.01	0.00	0.00
	XS 5+58	0.05	0.01	0.01	0.01	0.00

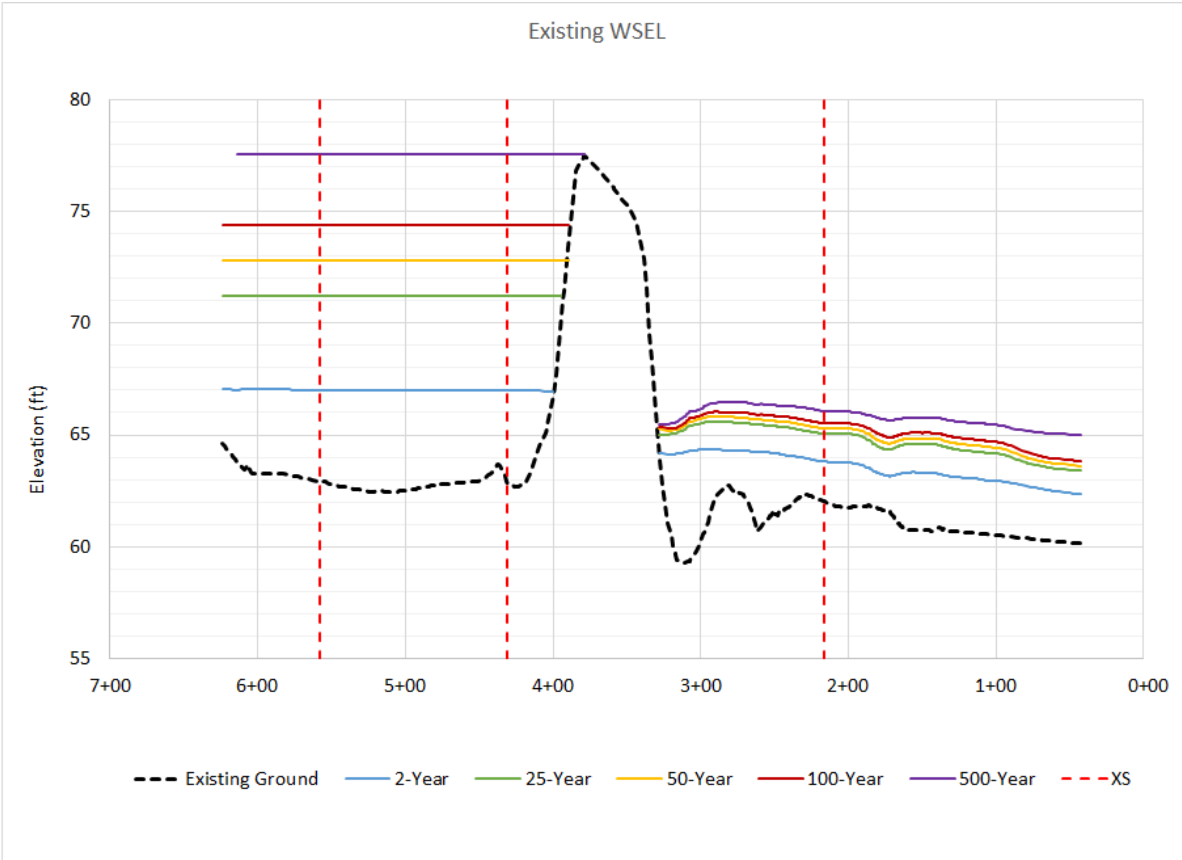

Figure 20 Existing conditions water surface profiles

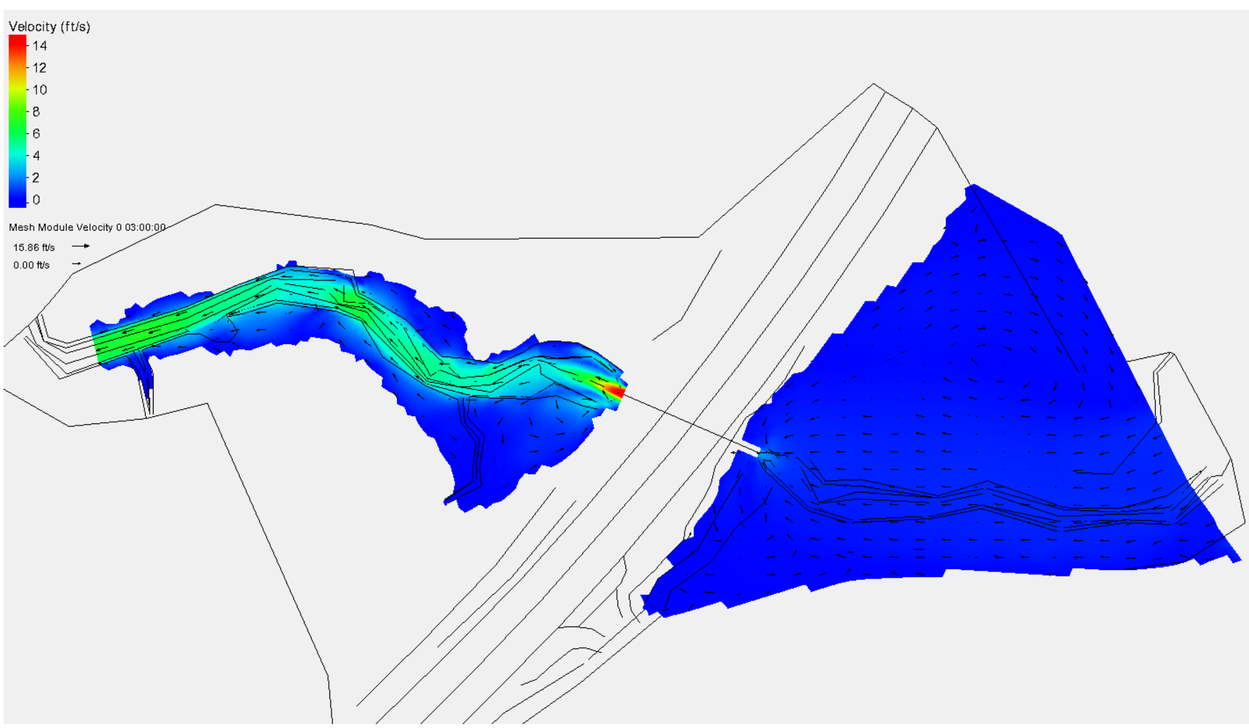

Figure 21 Existing conditions 100-year velocity map

7.2.2 Future conditions – Proposed 22 Foot Span Structure

Proposed conditions hydraulic results are summarized in Table 6. The proposed crossing is located at cross section STA 3+78. The larger proposed structure reduced water surface elevations upstream and did not result in any backwater (Figure 22). The 100-year water surface elevation upstream of the crossing was decreased by 7.7 feet when compared to existing conditions.

With the removal of the backwater condition, upstream channel velocities increased from existing conditions, varying from 3.11 ft/sec during the 2-year event to 4.17 ft/sec during the 100-year event. Downstream, velocities varying from 3.55 to 4.37 ft/sec. Similar to the velocity results, shear increased upstream of the crossing, varying from 0.37 to 0.58 lb/ft^2. At the downstream cross section shear stresses vary from 0.56 to 0.66 lb/ft^2.

When looking at the entire model domain, proposed velocities upstream of the crossing increased compared to existing conditions. The velocity at the outlet of the crossing decreases when compared to existing conditions (Figure 23). Velocities within the crossing are lower than upstream of the crossing. This is due to a backwater feature in the topography downstream. There is some deposition within the channel immediately downstream of the project grading that appeared to be causing the backwater. However, an additional model run was put together that removed this deposition and the backwater still occurred at the proposed structure. The backwater appears to be caused by the natural topography downstream of the crossing.

Table 6 Hydraulic results for proposed conditions within main channel

Hydraulic Parameter	Cross Section	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	XS 2+17	63.81	65.06	65.29	65.51	66.08
	XS 3+78	64.36	65.63	65.87	66.10	66.57
	XS 4+31	64.45	65.71	65.96	66.21	66.75
	XS 5+58	65.18	66.63	66.85	67.06	67.47
Max Depth (ft)	XS 2+17	1.79	3.04	3.27	3.50	4.06
	XS 3+78	2.50	3.77	4.01	4.24	4.71
	XS 4+31	2.13	3.40	3.65	3.90	4.43
	XS 5+58	2.29	3.74	3.95	4.17	4.58
Average Velocity (ft/s)	XS 2+17	3.55	3.99	4.22	4.37	4.30
	XS 3+78	2.31	2.79	2.94	3.11	3.47
	XS 4+31	3.11	4.11	4.16	4.17	4.13
	XS 5+58	3.76	3.36	3.43	3.50	3.67
Average Shear (lb/sq-ft))	XS 2+17	0.56	0.59	0.63	0.66	0.61
	XS 3+78	0.23	0.32	0.34	0.37	0.45
	XS 4+31	0.40	0.56	0.56	0.54	0.51
	XS 5+58	0.58	0.37	0.38	0.39	0.41

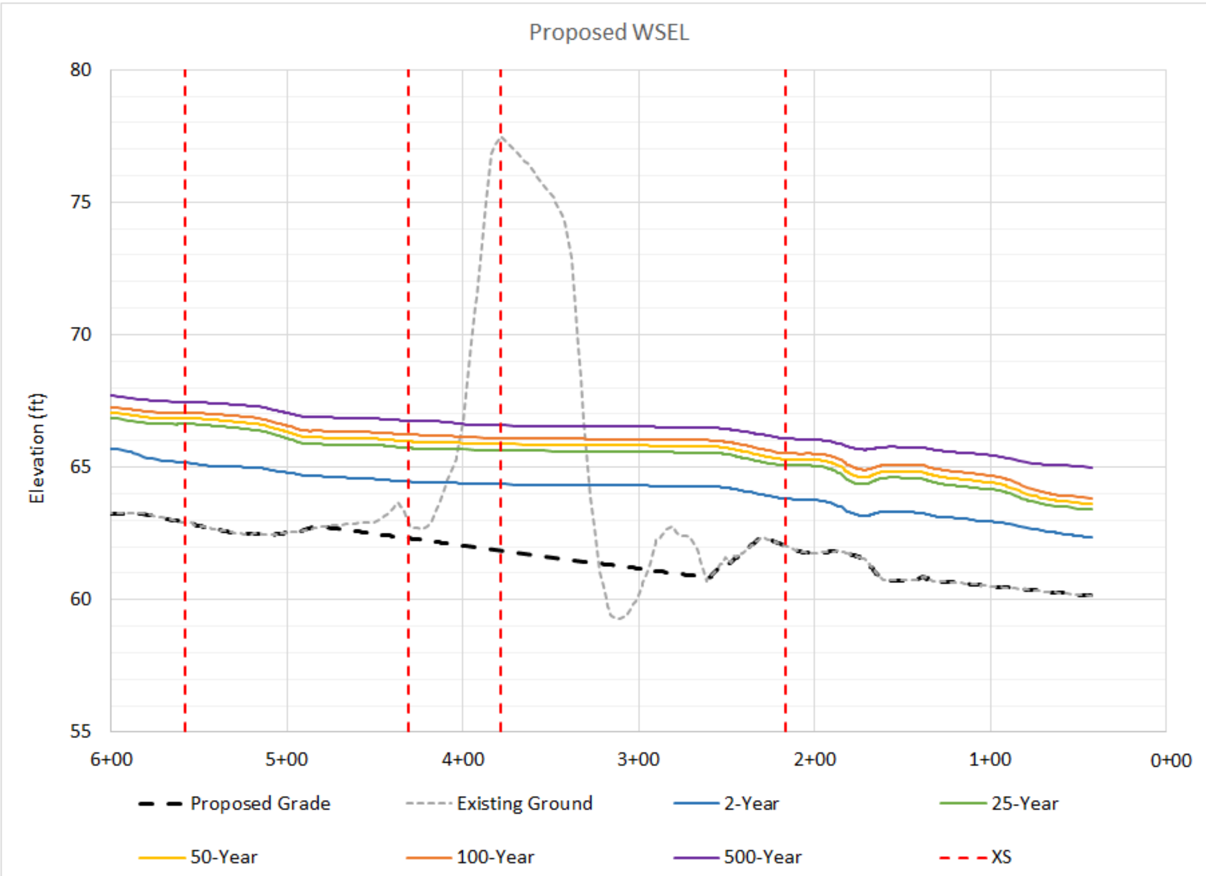

Figure 22 Proposed conditions water surface profiles

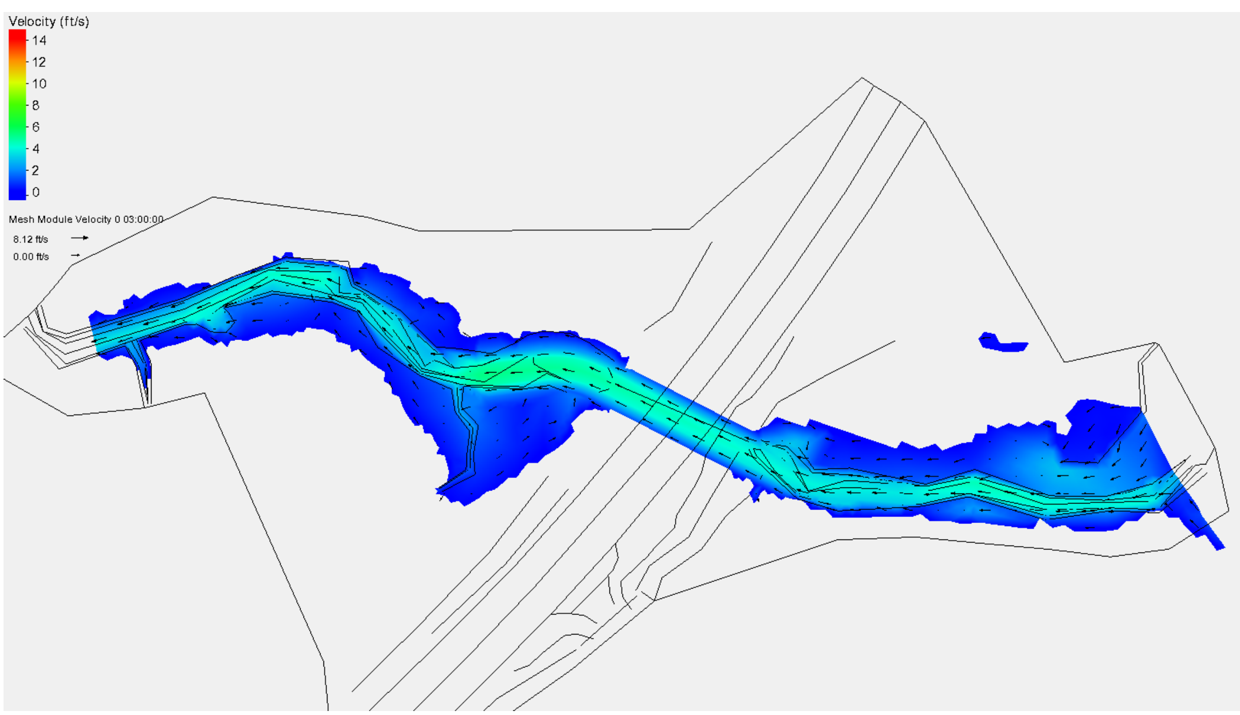

Figure 23 Proposed conditions 100-year velocity map

8.0 Fish Passage Design Methods Selection

8.1 Design Methodology Selection

The WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and bridge design method unless extraordinary circumstances exist on site. According to the WCDG, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bankfull width of greater than 15 feet, the channel is believed to be unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, or the culvert would be very long. Using these design criteria, bridge criteria was deemed the most appropriate method for this crossing because the bankfull width exceeds 15 feet.

8.2 Bridge Design Criteria

The 2013 WDFW Water Crossing Design Guidelines (WCDG) present two methodologies for designing a bridge crossing—confined bridge design and unconfined bridge design. The method to be used is defined by the Floodplain Utilization Ratio (FUR). The FUR is defined as the flood-prone width (FPW) divided by the bankfull width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood. A ratio under 3.0 is considered a confined channel and above 3.0 is considered an unconfined channel.

The upstream reach has a FPW that varies from approximately 34 feet to 43 feet. These FPW's are taken from the proposed conditions that removes the backwater pooling caused by the existing undersized culvert. Using the average measured bankfull width of 16 feet the FUR varies from 2.1 to 2.7.

8.2.1 Confined Bridge Design Width Criteria

The proposed crossing is a confined channel. The proposed structure size will follow the WCDG recommendation of span based on the agreed upon bankfull width. With the span being 1.2 x bankfull width + 2 feet (WCDG Equation 3.2). Using this equation, along with the measured bankfull width of 16 feet discussed in Section 5.0, results in a structure span of 21.2 feet. This was rounded up to the nearest whole foot of 22 feet.

8.2.2 Backwater and Freeboard

The WCDG recommends the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum 3 foot freeboard for streams of this size. It is practicable to meet the minimum 3 feet of freeboard at this crossing, as the road embankment height is approximately 14 feet above the proposed streambed elevation. The maximum water surface elevation at the crossing during the 100-year event is 66.11 feet at the assumed upstream bridge face location. In order to meet the minimum 3 feet of freeboard at the crossing a minimum low chord elevation of 69.11 is required.

An additional recommendation is that 5 feet of clearance from the channel thalweg to the low chord be provided if practicable to perform future maintenance, allowing for wildlife to cross, and performing monitoring activity. The 100-year water surface depth is approximately 4.23 feet above the thalweg. Therefore, the previous freeboard recommendation of 3 feet above the 100-year water surface provides the recommended minimum 5 feet of clearance.

8.2.3 Channel Planform and Shape

The WCDG requires that the channel planform and shape mimic conditions within a reference reach. The proposed channel shape includes 10H:1V slopes between the toes and 2H:1V bank slopes above the toe for 6 feet horizontally to create a 3-foot high bank. Above the 2H:1V bank slopes the grading transitions to 5H:1V to match existing grade (Figure 24). Upstream of the bridge the 5H:1V is not incorporated into the grading as the bank highs are already low, so the 2H:1V is used from the toe of the bank to catch existing grade, see Figure 25.

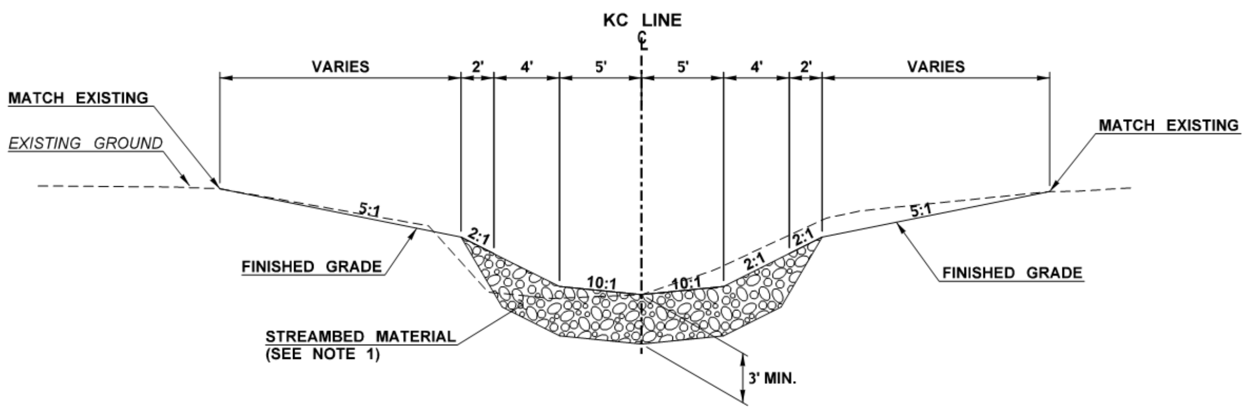

Figure 24 Typical downstream channel section (looking upstream)

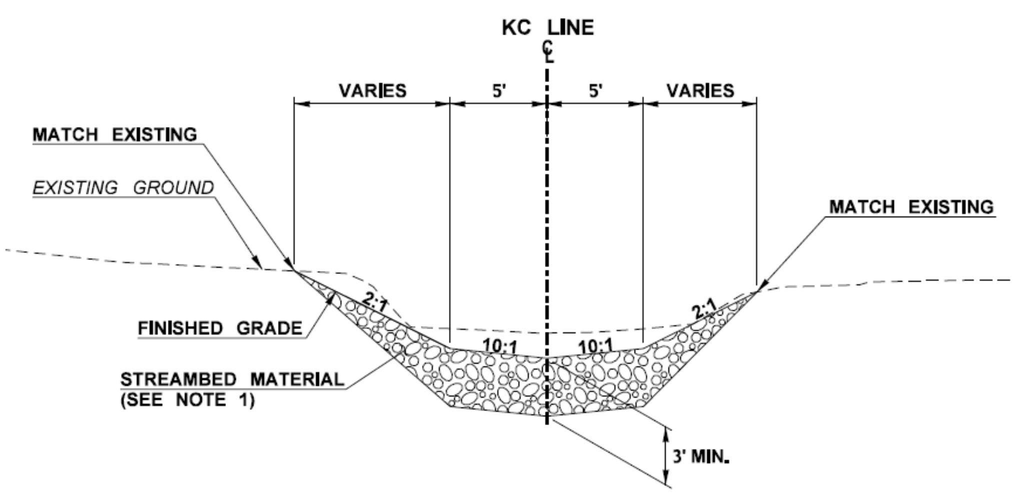

Figure 25 Typical upstream channel section (looking upstream)

8.2.4 Floodplain Continuity and Lateral Migration through Structure

The WCDG requires that bridges account for lateral channel movement that will occur in their design life and that the design channel maintains floodplain continuity. The channel is not expected to move significantly within its floodplain. The dense vegetation lining the stream banks throughout the observed reach and some channel incision suggests the stream has low potential to migrate within its floodplain.

8.2.5 Channel Gradient

The WCDG recommends to the extent compatible with safety of the structure, its approach roads, and adjacent private property, to allow natural evolution of the channel planform and longitudinal profile. The proposed slope for the reconstructed portion of the creek will be 0.88%. The average existing slope upstream of the crossing is approximately 0.75%, resulting in a slope ratio of 1.2. The slope through this reach is less than 1% over 300 feet upstream and 300 feet downstream of the crossing. The design slope appropriately represents the natural reach gradient.

9.0 Streambed Design

9.1 Alignment

The proposed alignment closely follows the existing stream alignment. The only change was upstream where the upstream end of the crossing was moved south several feet to reduce the skew of the structure at the road crossing. Channel grading will extend approximately 80 feet downstream of the crossing and 95 feet upstream of the crossing. The downstream channel grading end before the left bank tributary.

9.2 Proposed Section

Description of the existing and proposed cross section are presented in Section 8.2.3. A low flow channel will be added in later stages of the project that connect habitat features together and ensure the project is not a low flow barrier. The low flow channel will be as directed by the Engineer in the field.

9.3 Bed Material

The proposed bed material gradation was created using standard WSDOT specification material to mimic the gradation documented in the pebble count as best possible. The proposed mix will consists of 100% Streambed Sediment as it is the material that most closely represents the native streambed material observed during the site visit. A comparison of the observed and proposed streambed material size distribution is provided in Table 7.

Table 7 Comparison of observed and proposed streambed material

Particle	Observed Material Diameter (in)	Proposed Material Diameter (in)
D_{15}	0.2	0.02
D_{50}	0.6	1.0
D_{84}	1.1	2.0
D_{95}	1.5	2.4
D_{100}	2.5	2.5

9.4 Channel Habitat Features

Large Woody Material will be installed in portions of Kamilche Creek. These LWM installations will provide structures conducive to create stream complexity and geomorphic functions in segments that will have low natural LWM delivery rates while new and impacted riparian areas recover from construction activities related to the installation of the new crossing and the regrading of the stream channels. LWM, in conjunction with habitat boulders and bank-side bioengineering, will also help protect newly constructed banks and will promote long-term bed stability by creating pools, sinuosity, hard points, and channel roughness.

9.4.1 Design Concept

The 75th percentile of key piece density per Fox and Bolton (2007) and Chapter 10 of the Hydraulics Manual recommend 3.3 key pieces per 100 feet of channel. This percentile of wood placement is suggested to compensate for cumulative deficits of wood loading due to development. A conceptual LWM layout has been developed for the Kamilche Creek project area and is provided in Figure 26. The conceptual layout proposes 12 key pieces. The project reach is 220 feet long (including the area within the structure), yielding 5.5 key pieces per 100 feet of linear channel, 67% more than the Fox and Bolton (2007) 75th percentile criteria to account for portions of the channel where infrastructure limits LWM placement. The conceptual layout also includes boulder clusters under the proposed structure to provide stream complexity under the structure.

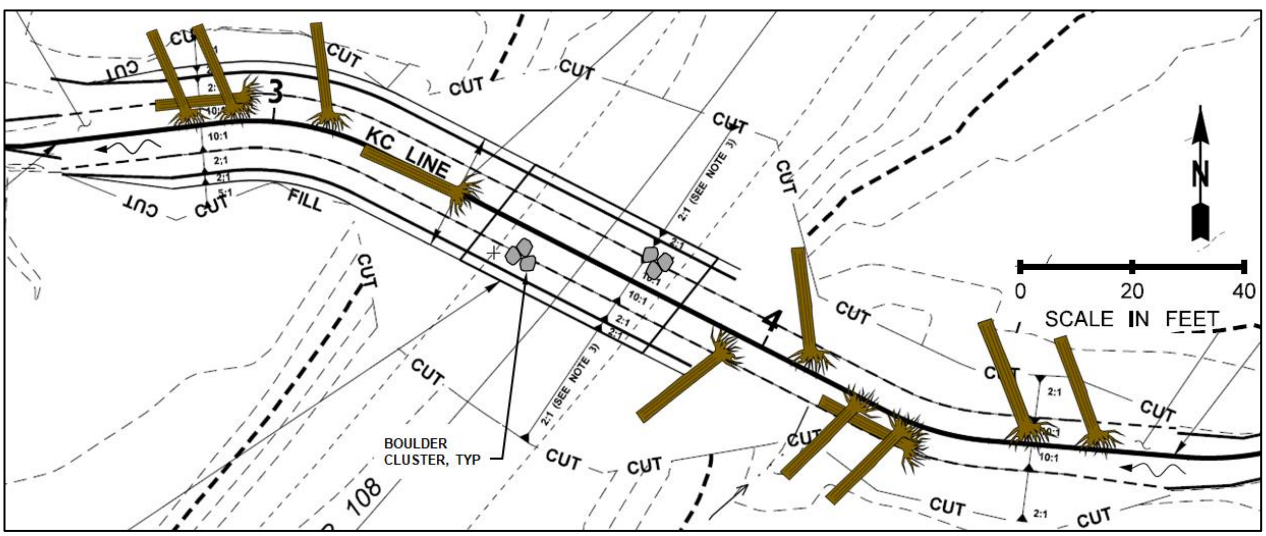

Figure 26 Proposed grading and conceptual wood layout

10.0 Floodplain Changes

This project is not within a FEMA mapped floodplain.

10.1 Floodplain Storage

Floodplain storage is anticipated to be nearly unaffected. There is some fill within the scour hole downstream of the culvert, however there is also removal of the undersized culvert, the existing roadway embankment and replacement with a larger hydraulic opening. The installation of a larger hydraulic opening reduces the amount of backwater being stored upstream of the crossing and also reduces any peak flow attenuation that was being provided by the smaller, existing culvert. Peak flow reduction was not quantified as the models were run in a quasi-steady state flow with a constant flow rate specified at the upstream boundary of the model.

10.2 Water Surface Elevations

Installation of the proposed structure will eliminate the backwater impacts upstream of the existing culvert, resulting in a reduction in water surface elevation. Preliminary hydraulic results indicate that there is a reduction in water surface elevation of 7.7 and 10.8 feet during the 100 and 500-year events at the upstream cross section, respectively. Just downstream of the culvert, the proposed grading fills the scour pool, creating a water surface elevations increase of approximately 1.2 feet during the 100 year event.

Figure 27 Existing and proposed 100-Year water surface profile comparison

Figure 27 provides a comparison of the existing and proposed 100-year water surface profile, showing the areas of increase of greater than 0.1 feet during proposed conditions. The hydraulic simulations indicate an increase in water surface elevations downstream of the proposed crossing with a maximum increase of approximately 0.7 feet. The increase in water surface can be attributed to the filling of the scour pool downstream. Increases in the 100-year water surface are illustrated in Figure 28.

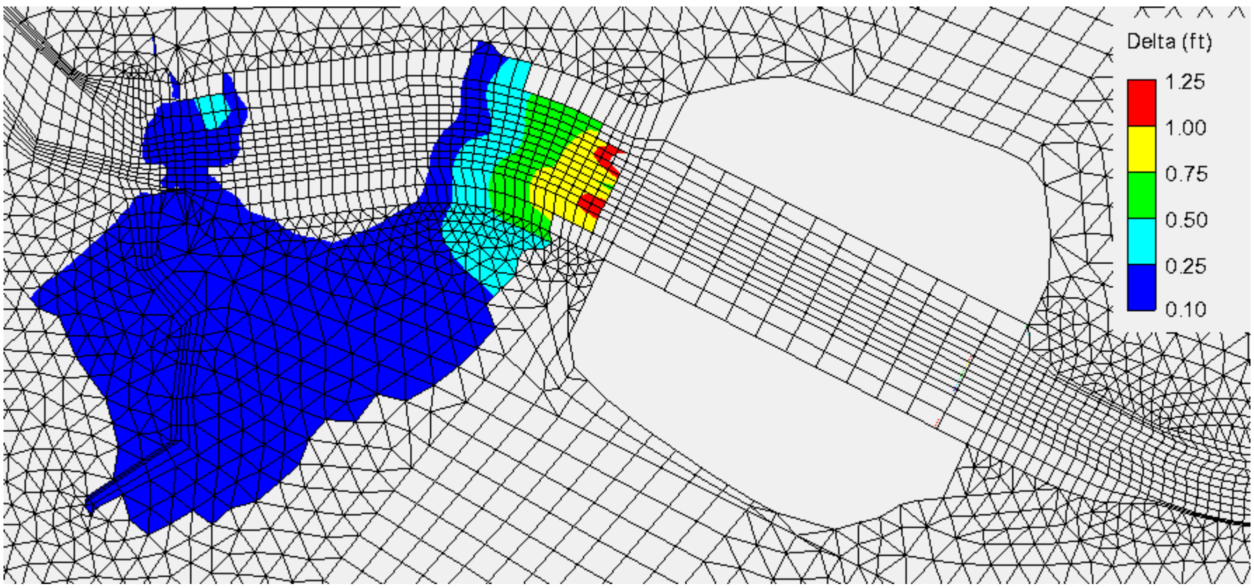

Figure 28 Areas of water surface elevation increase for the 100-year water surface

11.0 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges, and buried structures through a risk based assessment beyond the design criteria. For bridges and buried structures, the largest risk to the structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system.

11.1 Climate Resilience Tools

Climate resilience is evaluated at each crossing using the Climate Impacts Vulnerability Assessment Maps created by WSDOT to assess risk level of infrastructure across the state. The SR 108 crossing at Kamilche Creek has been evaluated and determined to be a low risk site based on the Climate Impacts Vulnerability Assessment Maps.

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. For low or medium risk sites, the 2040 percent increase is used. For high risk sites the 2080 percent increase is used. Appendix C contains the information received from WDFW for this site. The 100-year flow event was chosen to be evaluated, because, as it is an extreme event, if the channel behaves similarly through the structure during this event as it does the adjacent reaches, then it is anticipated this relationship would also be true at lower flows as well.

11.2 Hydrology

For each design WSDOT uses the best available science for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgment is used to compare model results to system characteristics; if there is significant variation, then the hydrology is re-evaluated to determine whether or not adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2040 projected 100-year flow event to check for climate resiliency. The design flow for the crossing 238 cfs at the 100-year storm event. The projected increase for the 2040 flow rate is 7.5%, yielding a projected 2040 flow rate of 256 cfs.

11.3 Structure Width

The minimum width for a crossing given by Equation 3.2 was 21.2 feet. Structures come in whole foot increments for width, as a result, the width was increased to 22 feet to accommodate constructability and manufacturability. This structure width was evaluated at the 100-year flow event and projected 2040 100-year flow event and determined to produce similar velocities through the structure and adjacent reaches as the existing 100-year flow event. The velocity comparisons for these flow rates can be seen in Table 8 below.

Table 8 Velocity comparison for 20 foot structure

	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	Difference (ft/s)	Difference (%)
Upstream of Structure	4.17	4.18	0.01	0.24
Through Structure	3.11	3.21	0.20	6.23
Downstream of Structure	4.37	4.42	0.05	1.13
Velocity Ratio	0.75	0.77	-	-

Note: Velocity ratio calculated as Vstructure/Vupstream

11.4 Freeboard and Countersink

The minimum recommended freeboard at this location based on bankfull width is 3 feet at the 100-year flow event. The water surface elevation is projected to increase by 0.12 feet for the 2040 projected 100-year flow rate when compared to the 100-year flow event at the upstream bridge face. The minimum low chord of the structure was increased by 0.12 feet and set to elevation 69.24 feet to provide 3 feet of freeboard during the projected 2040 100-year flow event to accommodate climate resilience.

Long term degradation and aggregation, contraction scour and local scour were not evaluated for this preliminary hydraulic design and will need to be evaluated during the final design. Pending the outcome of the scour analysis, the preliminary design and depth of countersink will be revised to account for the total potential scour associated with the projected 2040 100-year flow event.

11.5 Summary

A minimum hydraulic opening of 22 feet and a minimum freeboard of 3.12 feet at existing 100-year flow event, or 3 feet at the projected 2040 100-year flow rate, allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2040 100-year flow event. This will provide a robust structure design that is resilient to climate change and allow the system to function naturally, including the passage of sediment, debris and water in the future.

12.0 Scour Analysis

Scour calculations were not performed during the preliminary design, but will be performed following the procedures outlined in *Evaluating Scour at Bridges HEC No. 18* (Arneson et al. 2012) during final design. Scour components to be considered in the analysis include:

1. Long-term aggradation/degradation
2. General scour (i.e., contraction scour)
3. Local scour

In addition to the three scour components above, potential lateral migration of a channel must be assessed when evaluating total scour at highway infrastructure.

13.0 References

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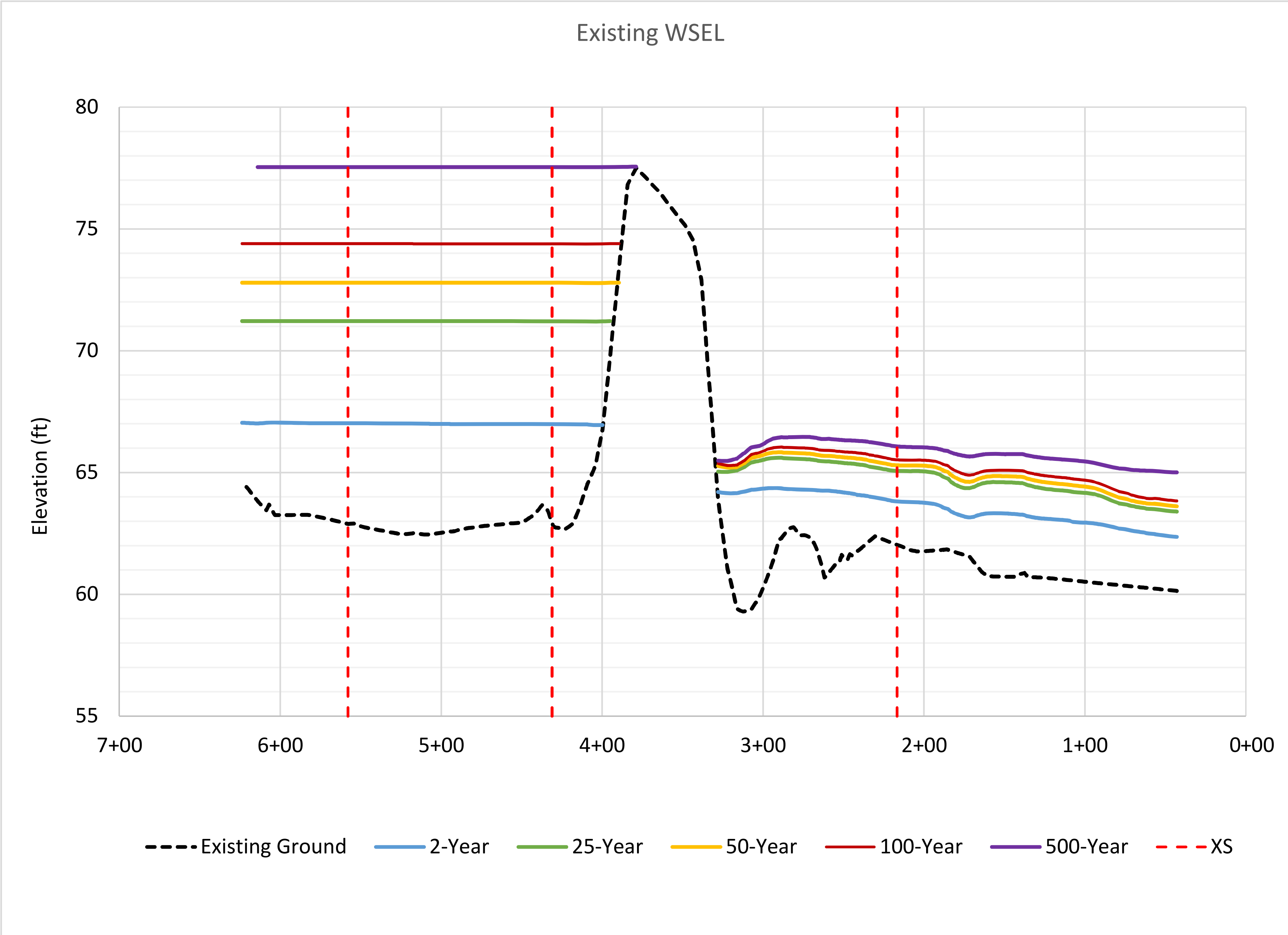
14.0 Appendices

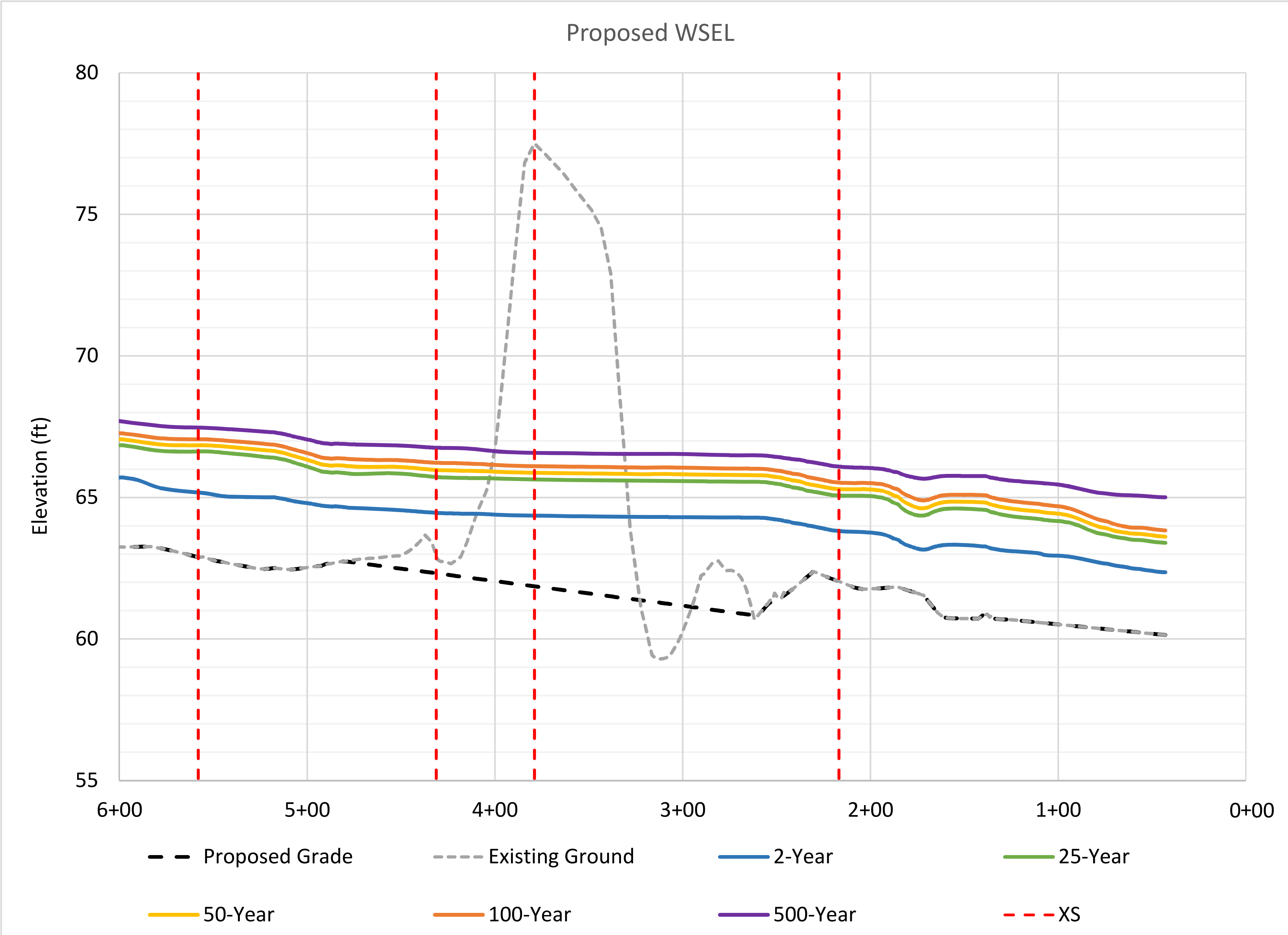
Appendix A – SRH-2D Model Results

Appendix B – Stream Plan Sheets, Profile, Details

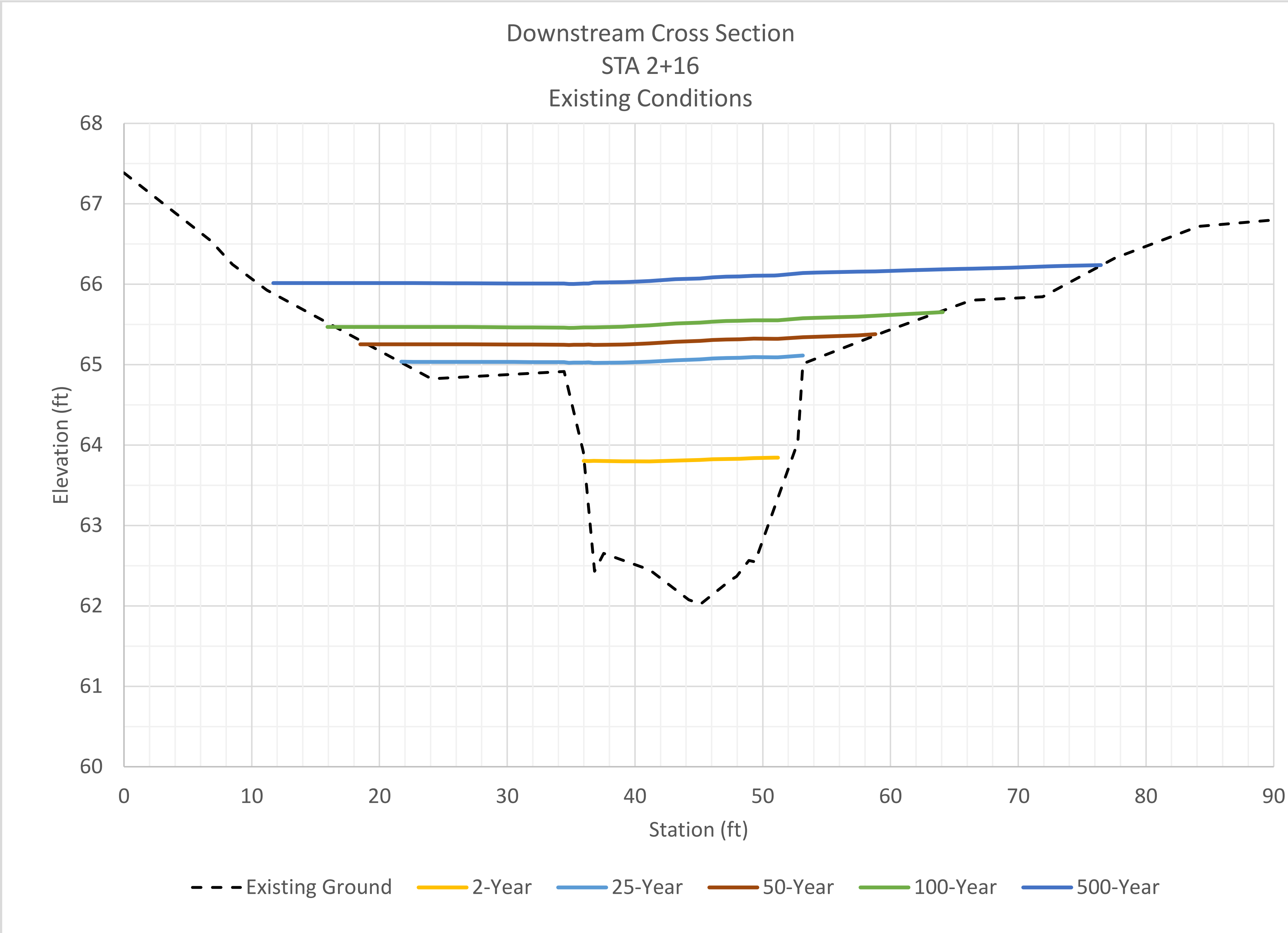
Appendix C—WDFW Future Projections for Climate-Adapted Culvert Design Printout

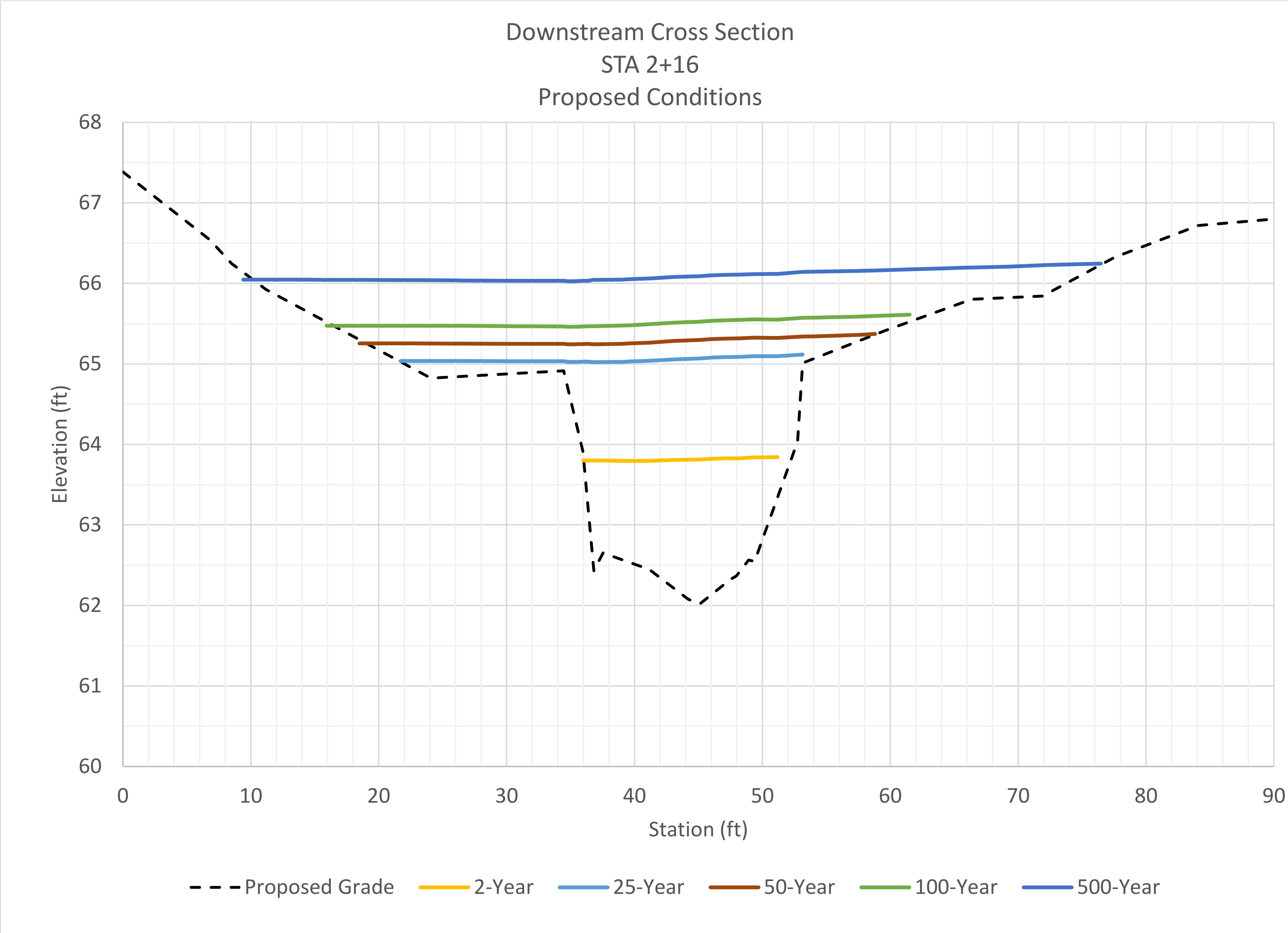
Appendix A – SRH-2D Model Results

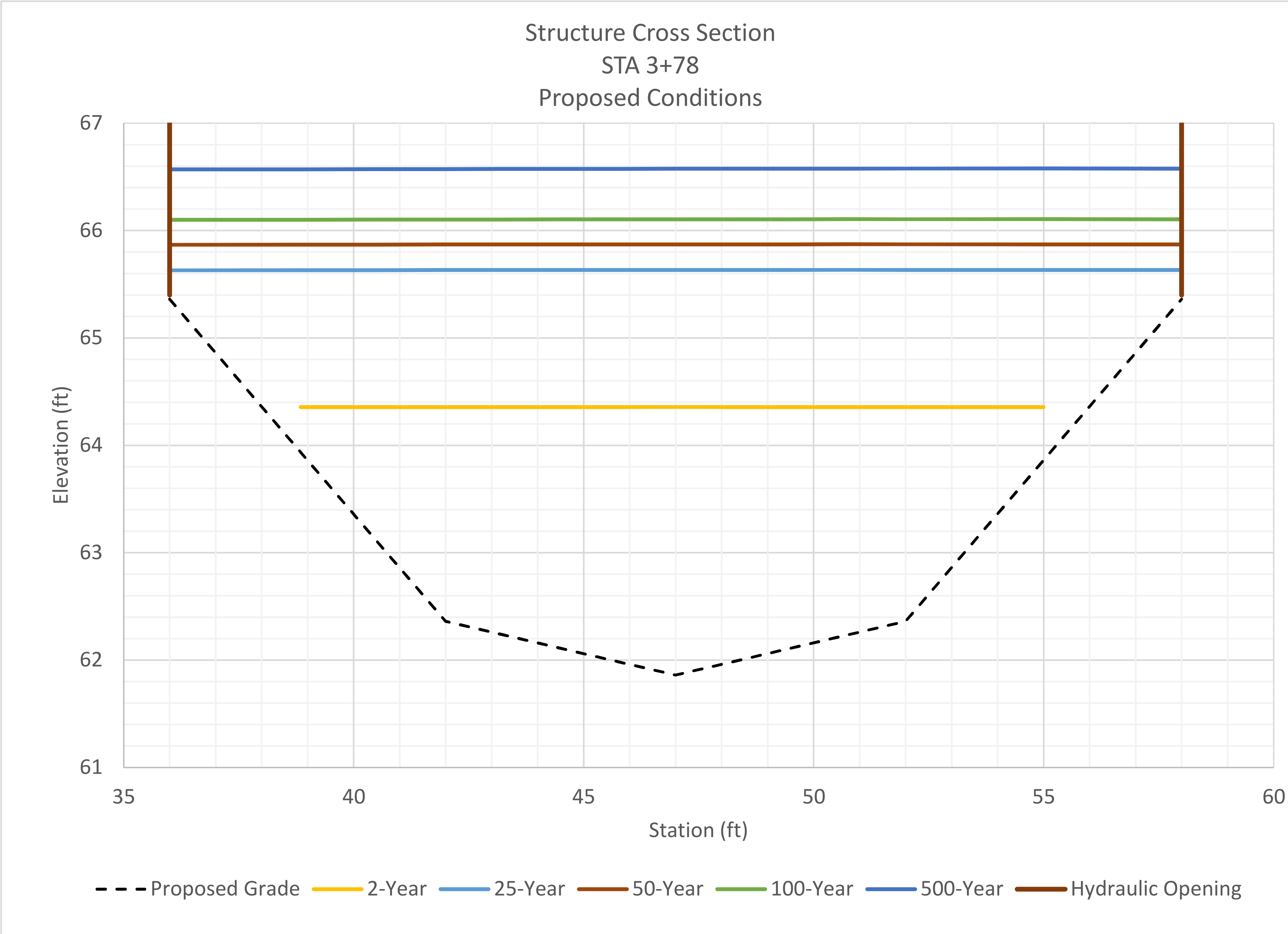

Existing WSEL
Elevation (ft)
80
75
70
65
60
55
7+00
6+00
5+00
4+00
3+00
2+00
1+00
0+00
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year
XS



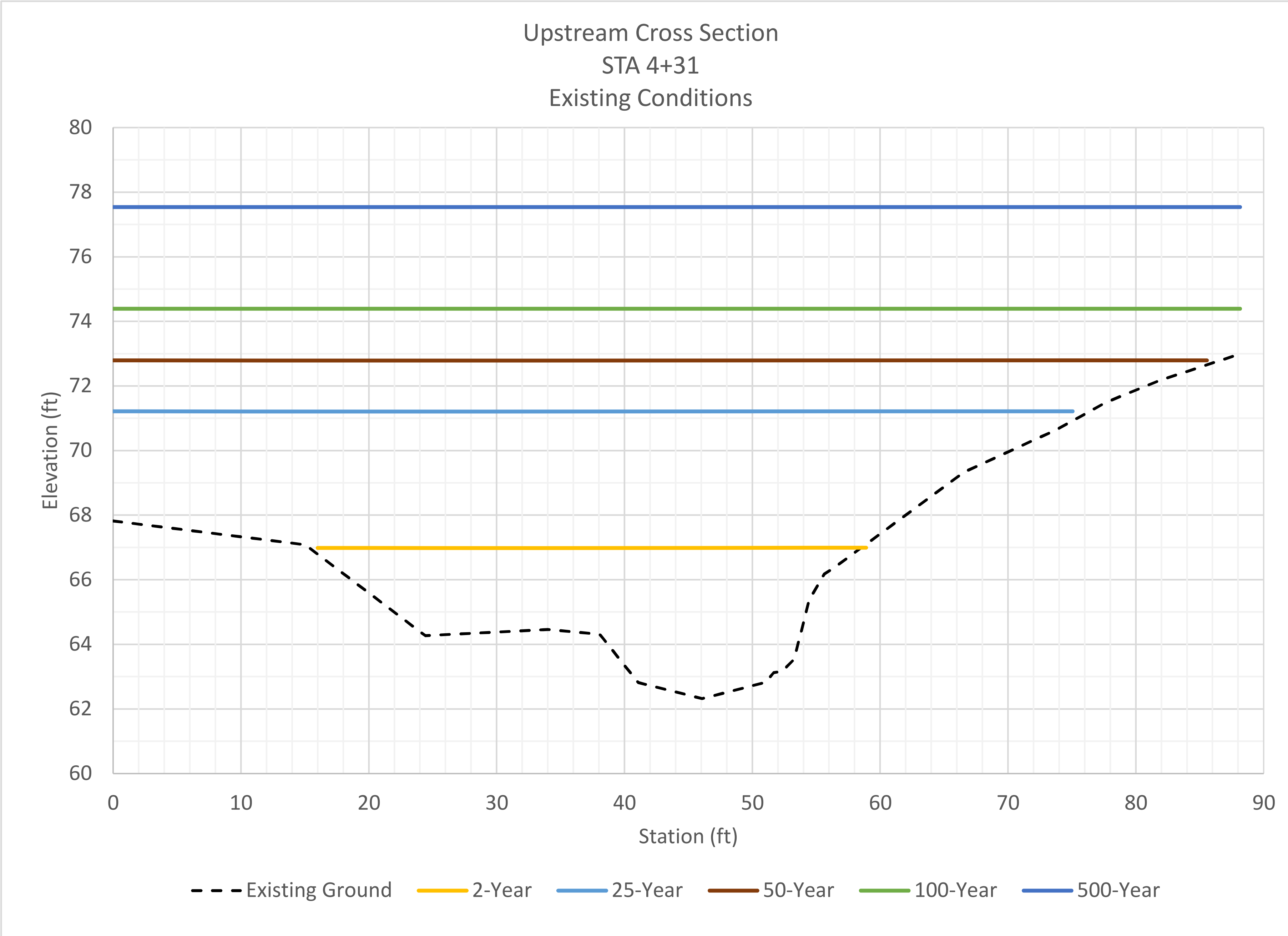
Proposed WSEL
80
75
70
65
60
55
Elevation (ft)
6+00
5+00
4+00
3+00
2+00
1+00
0+00
Proposed Grade
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year
XS

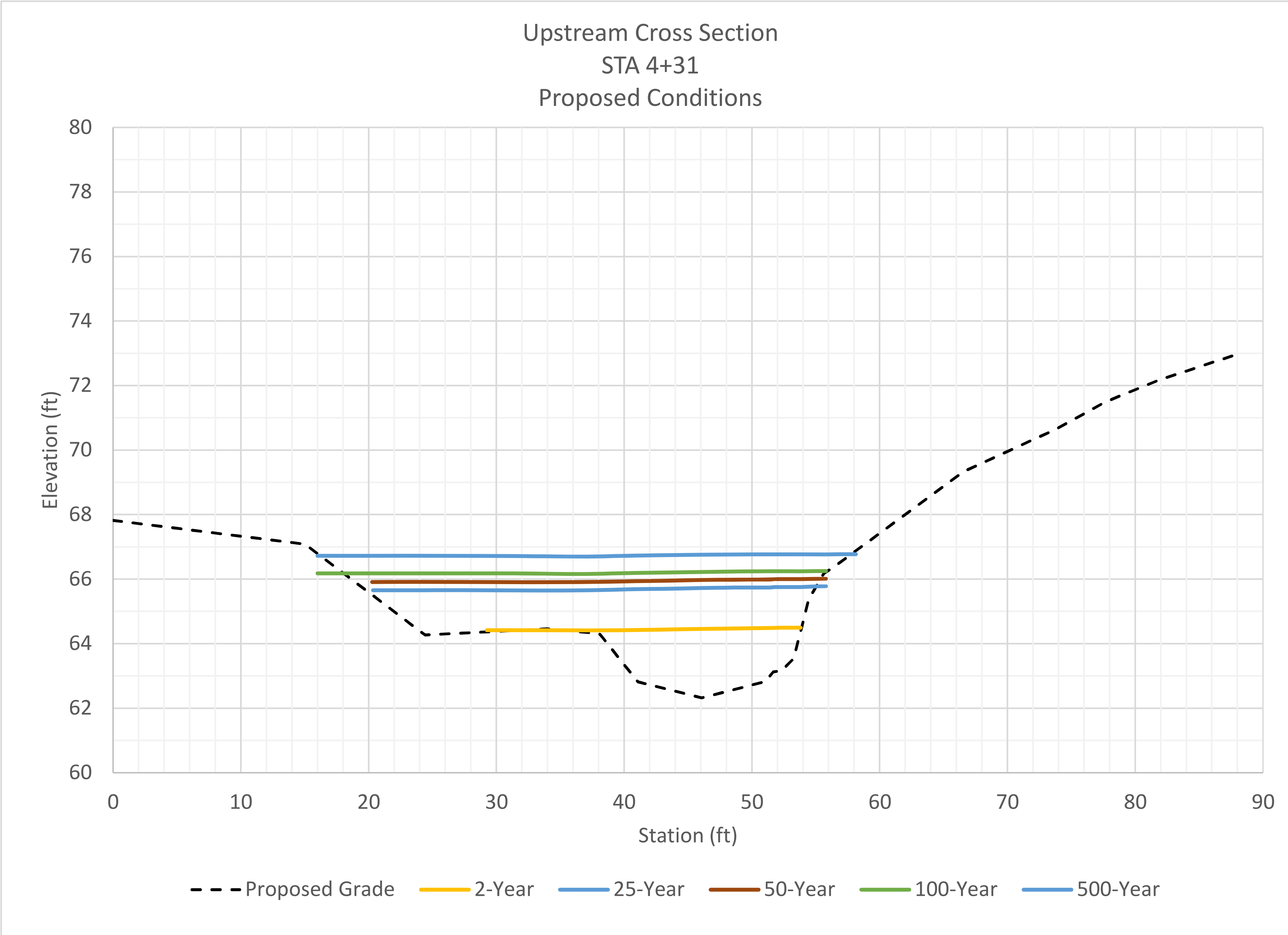

Downstream Cross Section
STA 2+16
Existing Conditions
Elevation (ft)
68
67
66
65
64
63
62
61
60
0
10
20
30
40
50
60
70
80
90
Station (ft)
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year

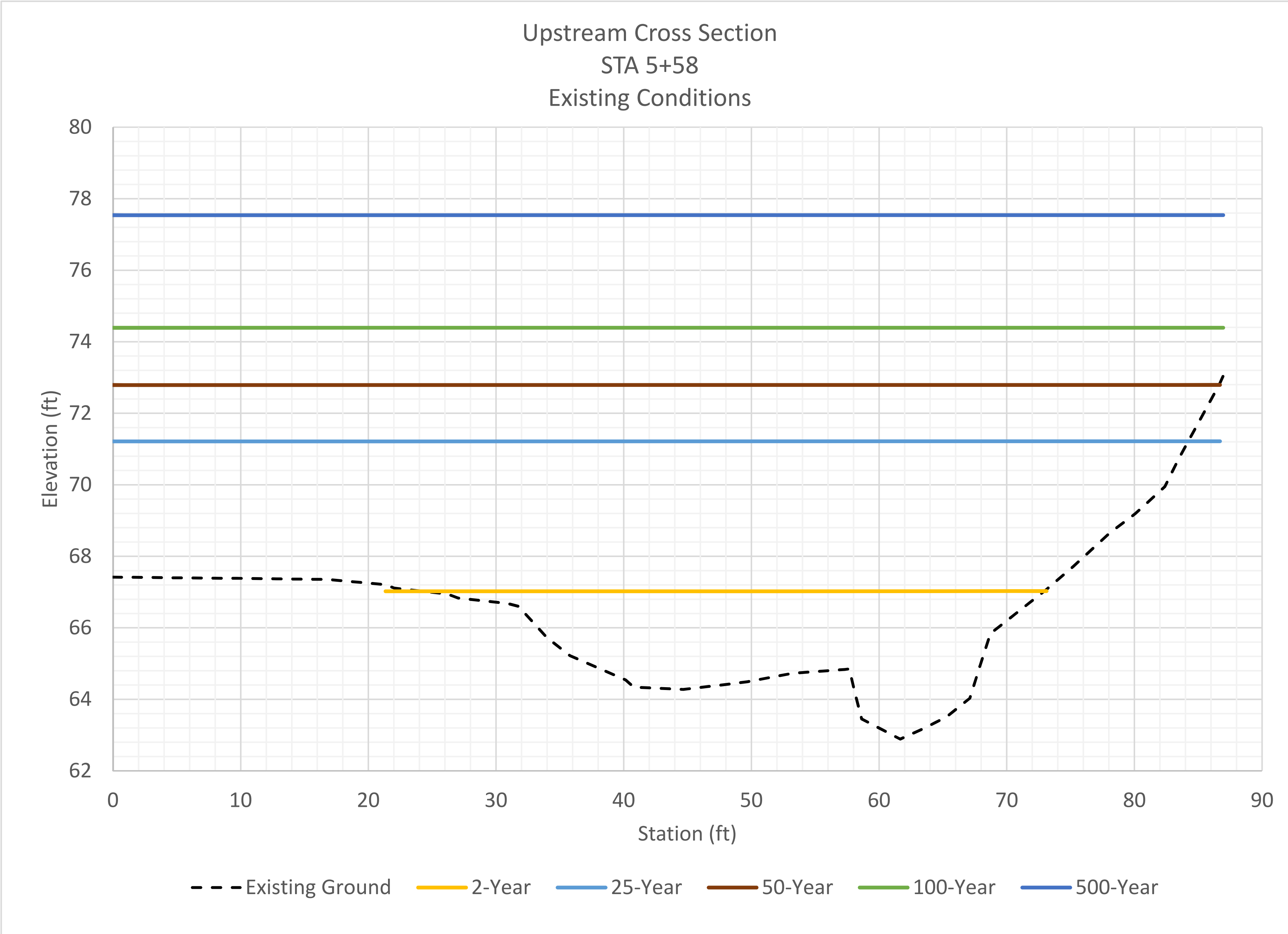

Downstream Cross Section
STA 2+16
Proposed Conditions
Elevation (ft)
68
67
66
65
64
63
62
61
60
0
10
20
30
40
50
60
70
80
90
Station (ft)
Proposed Grade
2-Year
25-Year
50-Year
100-Year
500-Year

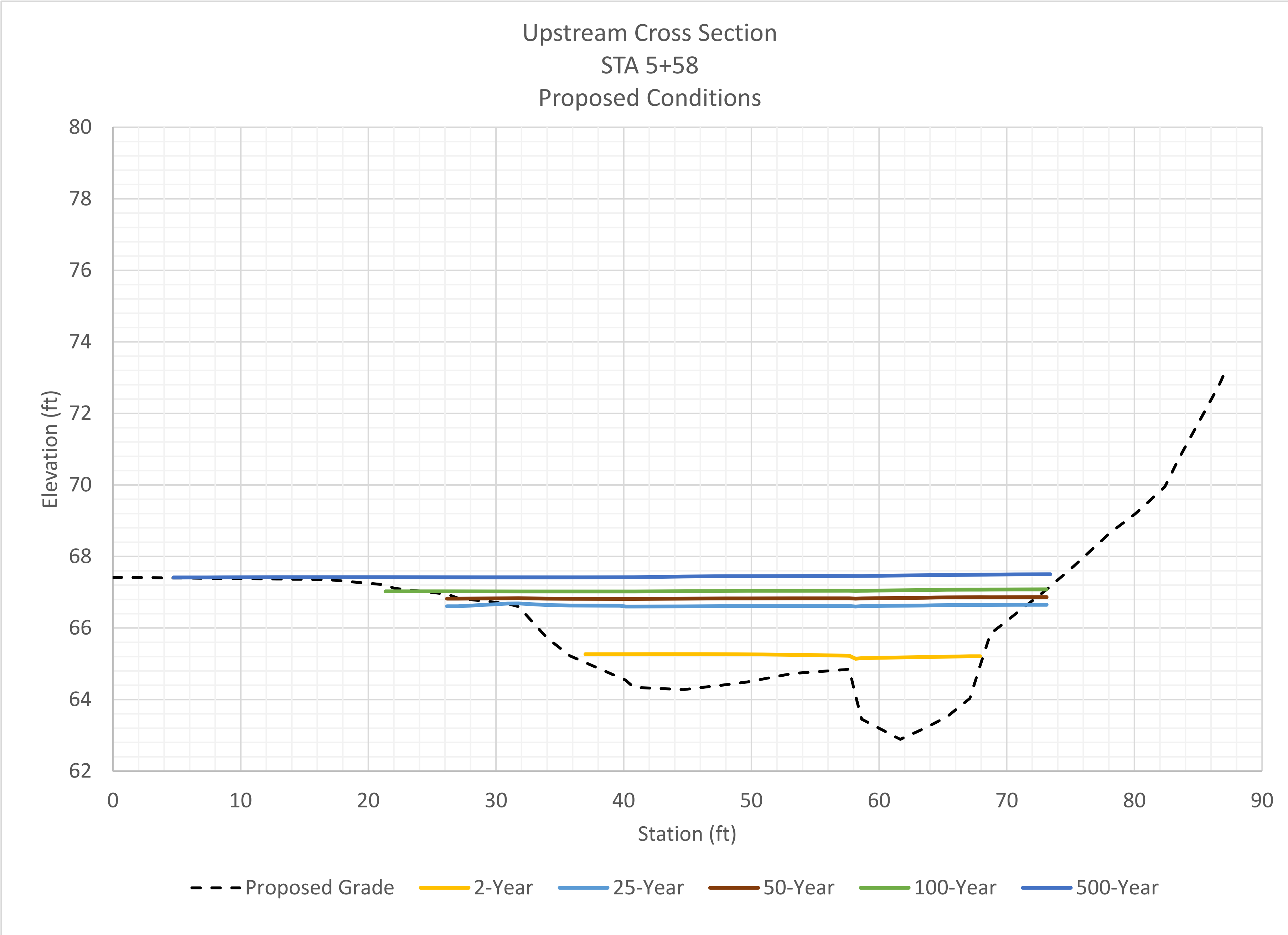


Structure Cross Section
STA 3+78
Proposed Conditions
Elevation (ft)
67
66
65
64
63
62
61
35
40
45
50
55
60
Station (ft)
Proposed Grade
2-Year
25-Year
50-Year
100-Year
500-Year
Hydraulic Opening


Upstream Cross Section
STA 4+31
Existing Conditions
Elevation (ft)
80
78
76
74
72
70
68
66
64
62
60
0
10
20
30
40
50
60
70
80
90
Station (ft)
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year

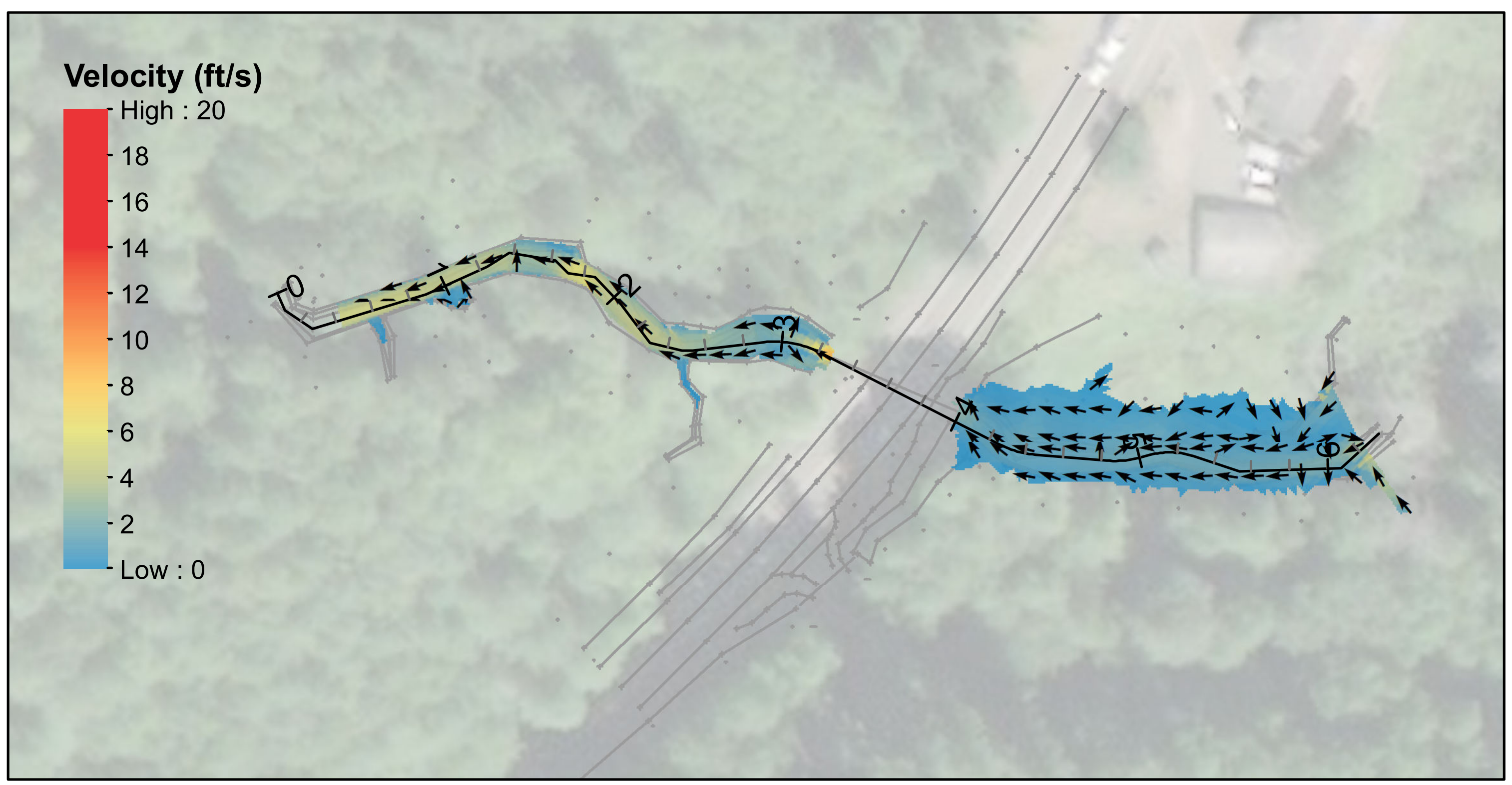

Upstream Cross Section
STA 4+31
Proposed Conditions
Elevation (ft)
80
78
76
74
72
70
68
66
64
62
60
0
10
20
30
40
50
60
70
80
90
Station (ft)
Proposed Grade
2-Year
25-Year
50-Year
100-Year
500-Year


Upstream Cross Section
STA 5+58
Existing Conditions
Elevation (ft)
Station (ft)
80
78
76
74
72
70
68
66
64
62
0
10
20
30
40
50
60
70
80
90
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year


Upstream Cross Section
STA 5+58
Proposed Conditions
Elevation (ft)
80
78
76
74
72
70
68
66
64
62
0
10
20
30
40
50
60
70
80
90
Station (ft)
Proposed Grade
2-Year
25-Year
50-Year
100-Year
500-Year

WATER SURFACE ELEVATION

DEPTH



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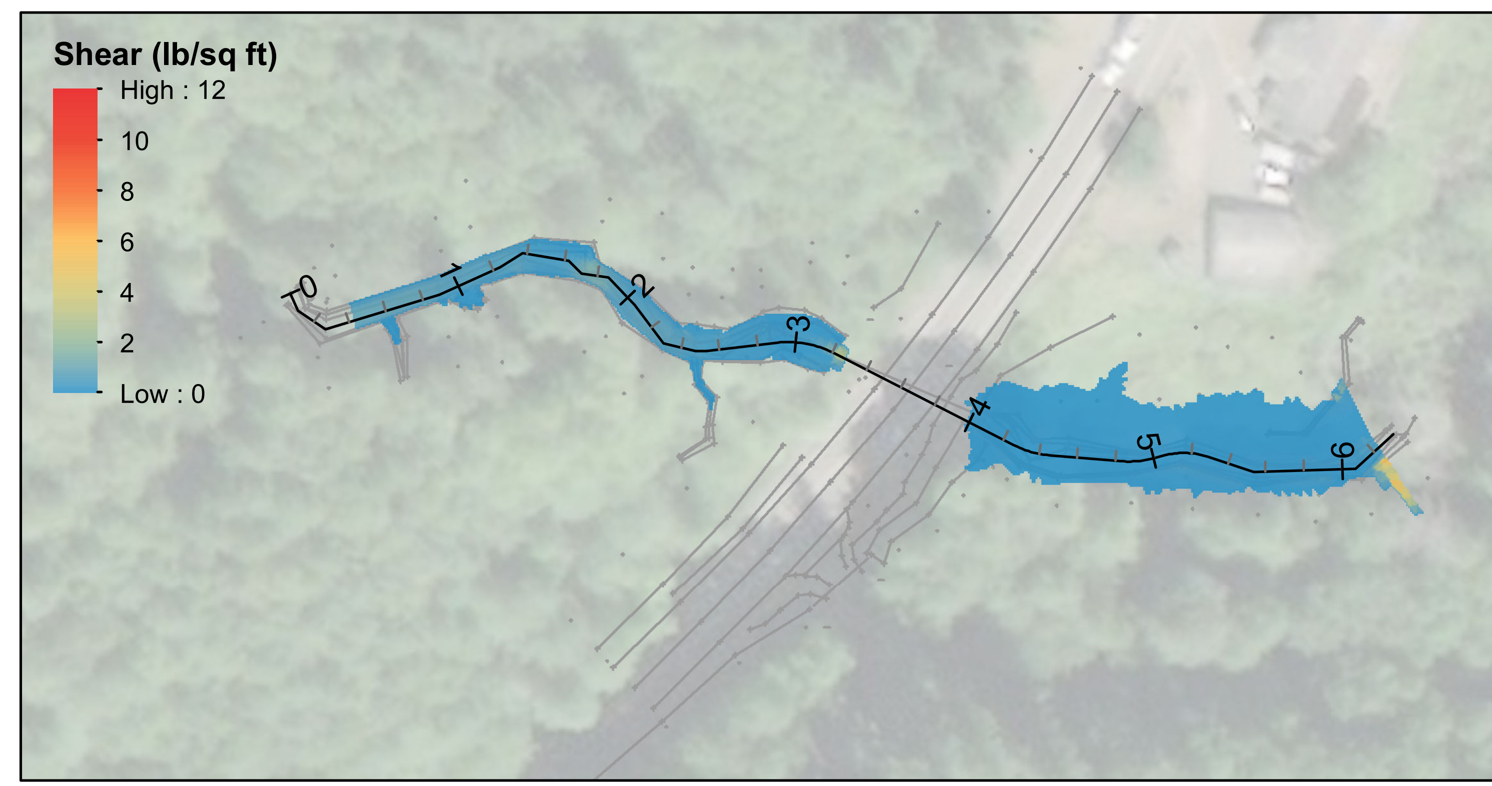

SHEAR

N

0 75 150 Feet

HDR

Washington State Department of Transportation

EXISTING CONDITIONS - 2 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

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PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION

DEPTH

VELOCITY

SHEAR

N

0 75 150 Feet

Washington State Department of Transportation

PROPOSED CONDITIONS - 2 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

PATH: S:\SR108\MP9.47KAMILCHE\SMS\RESULTS\OUTPUT FIGURES\PROPOSED_2YR FINAL.MXD - USER: DMINNER - DATE: 10/7/2019

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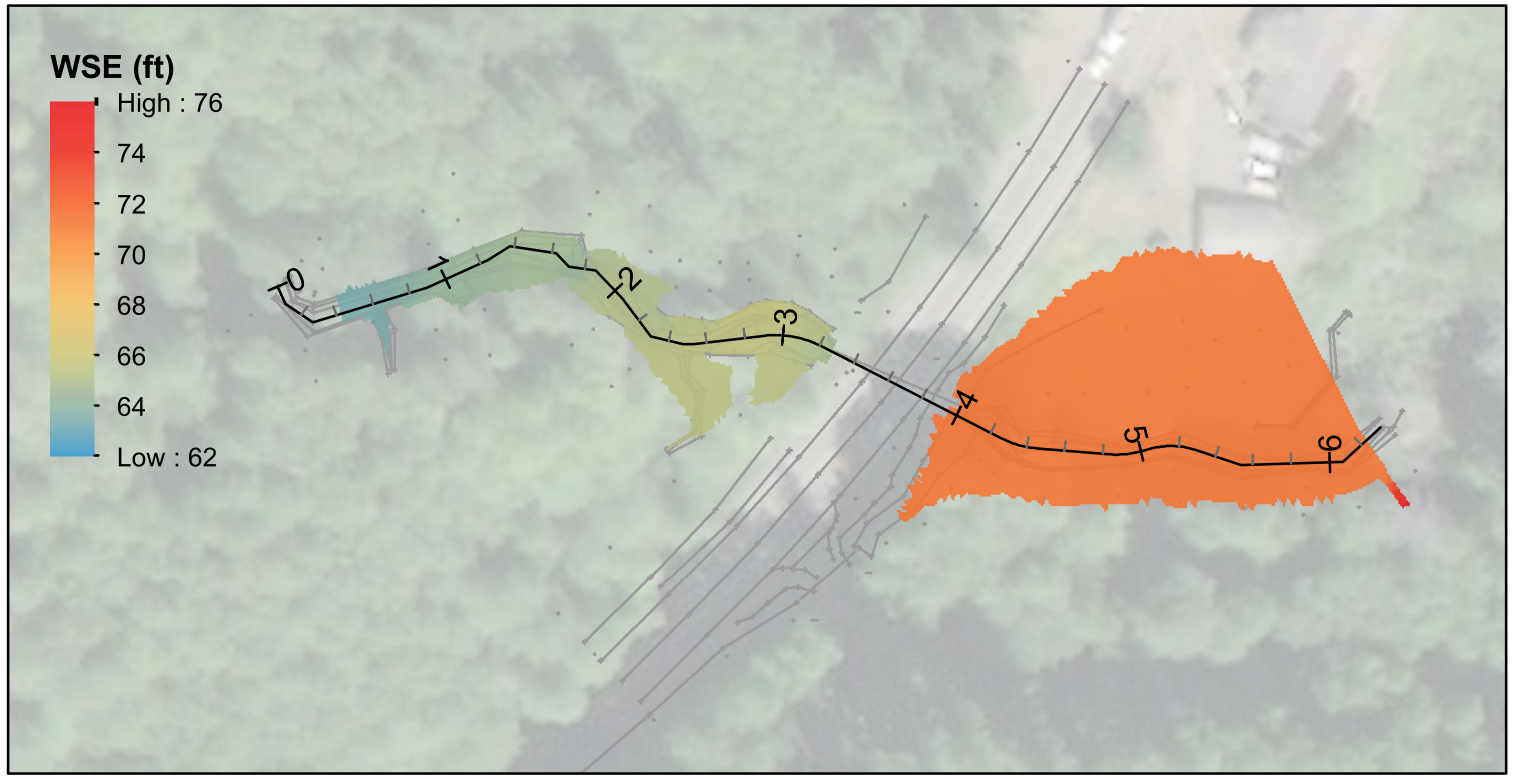

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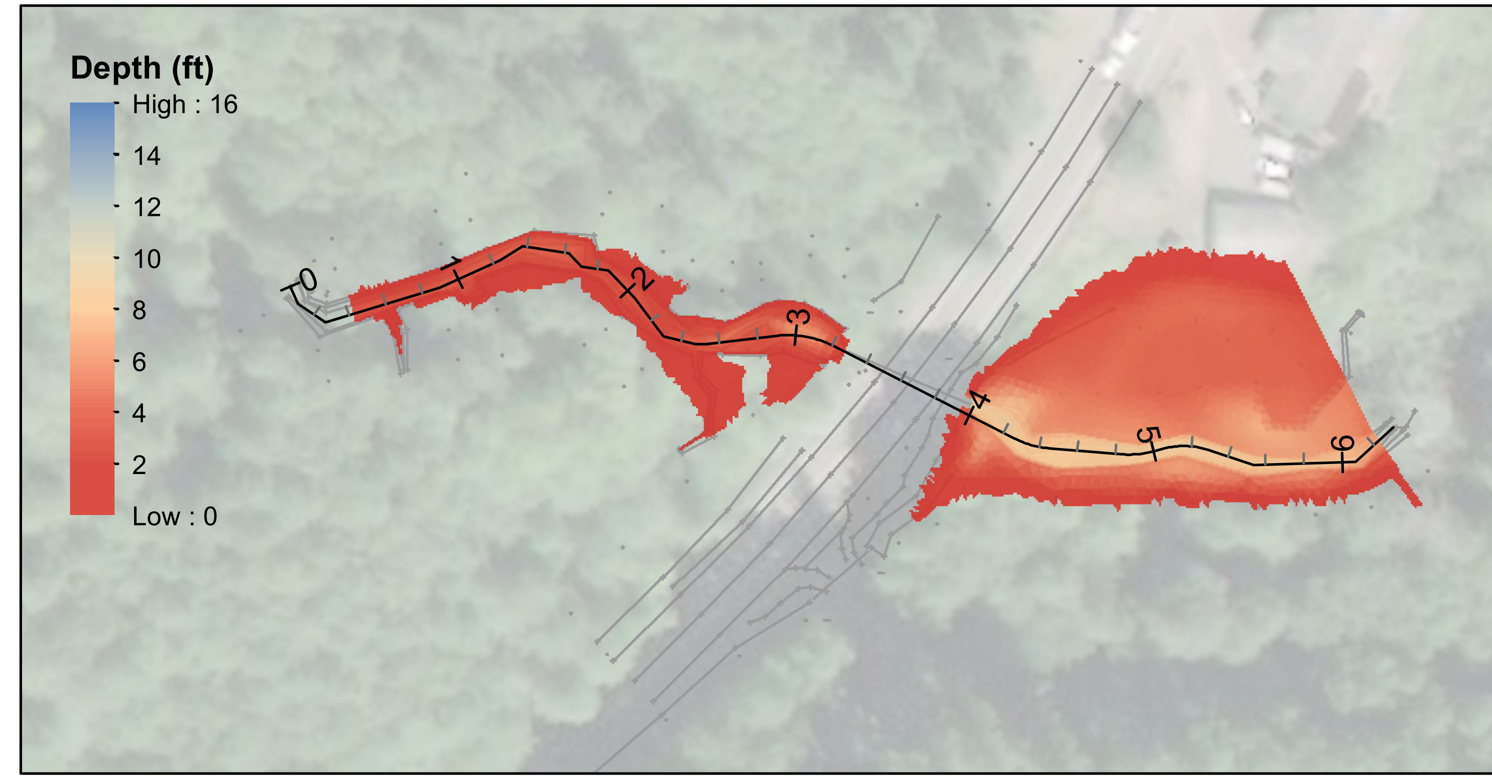
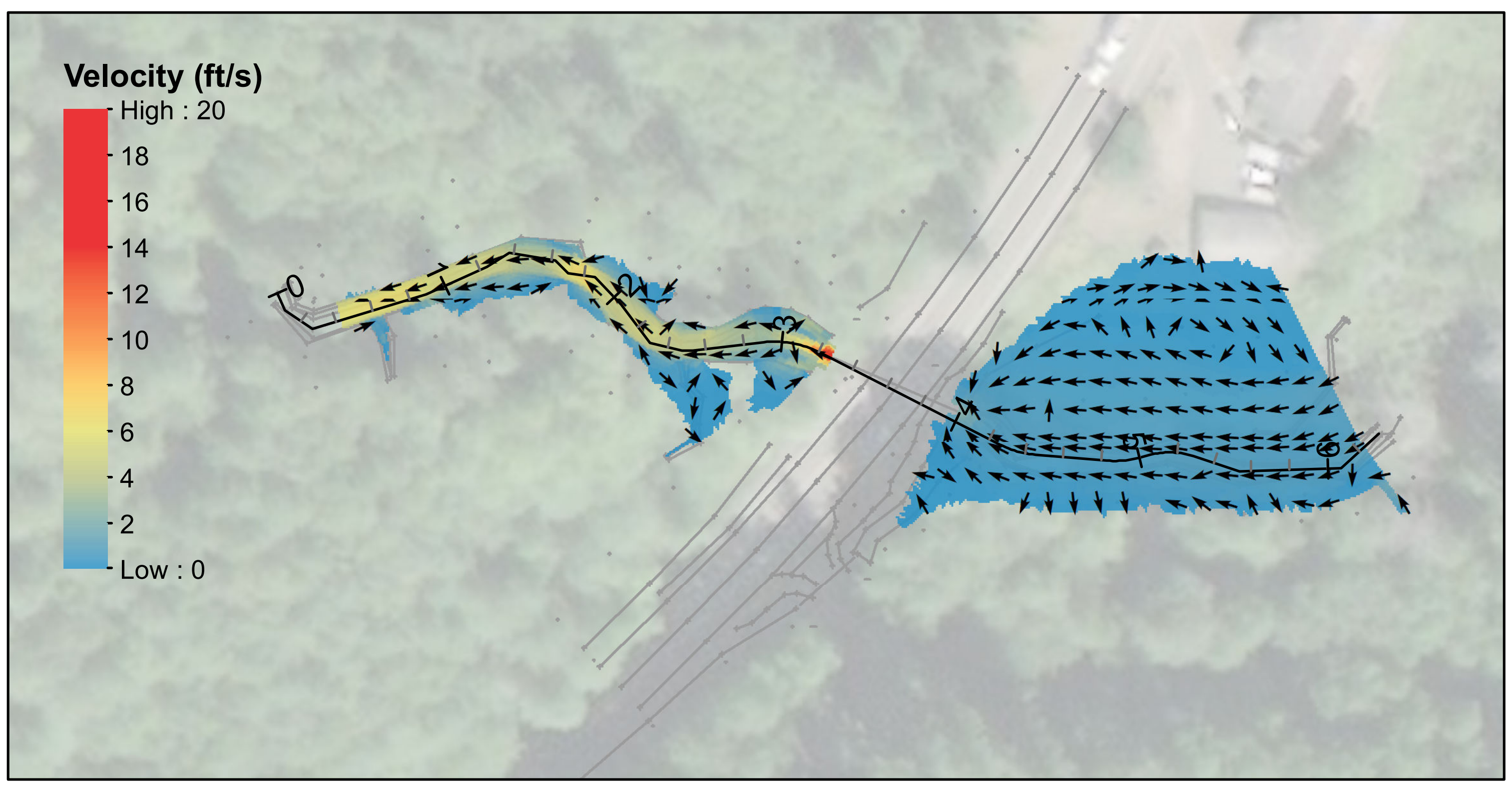


DEPTH



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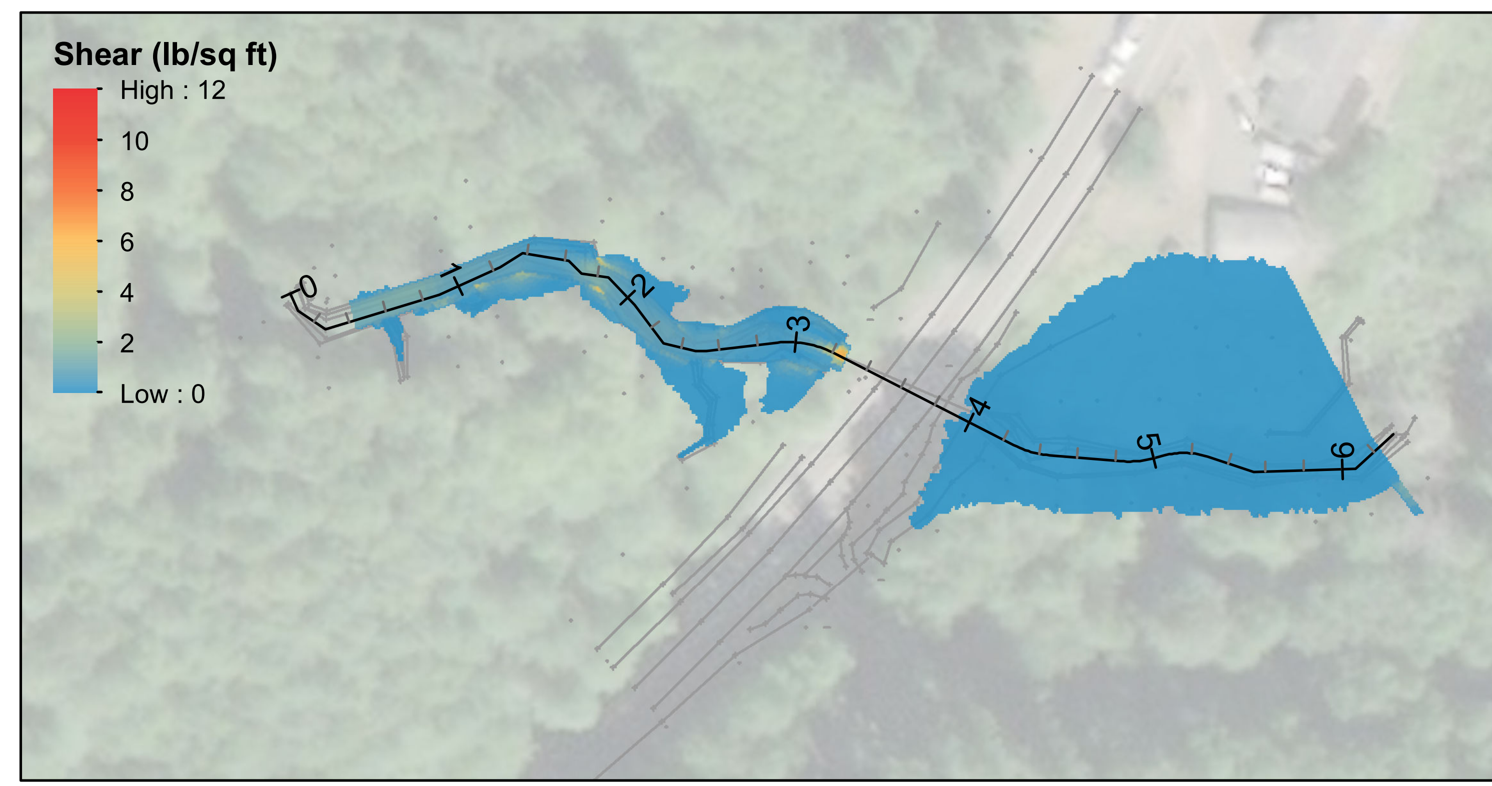

SHEAR

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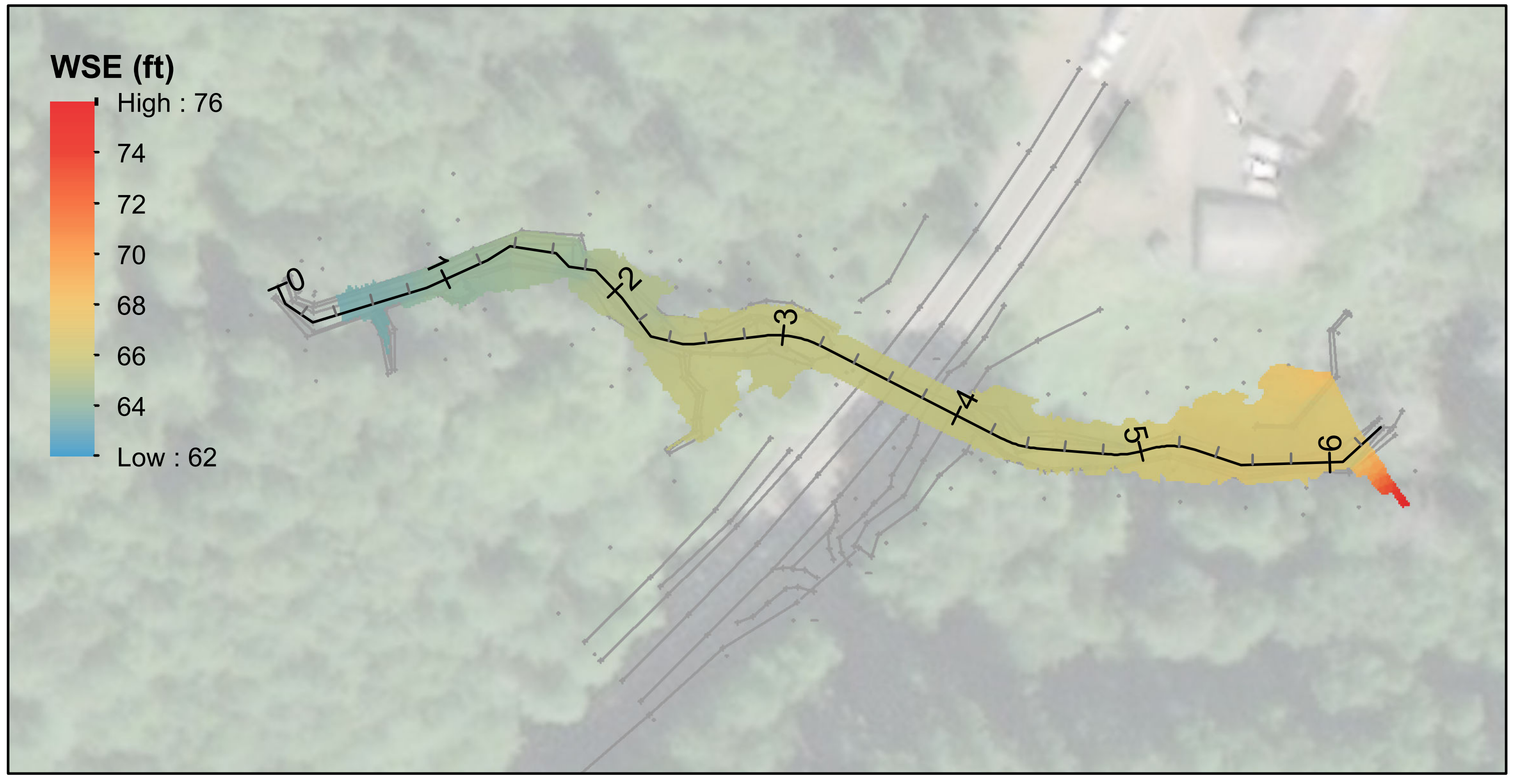
0 75 150 Feet

HDR

Washington State Department of Transportation

EXISTING CONDITIONS - 25 YEAR EVENT

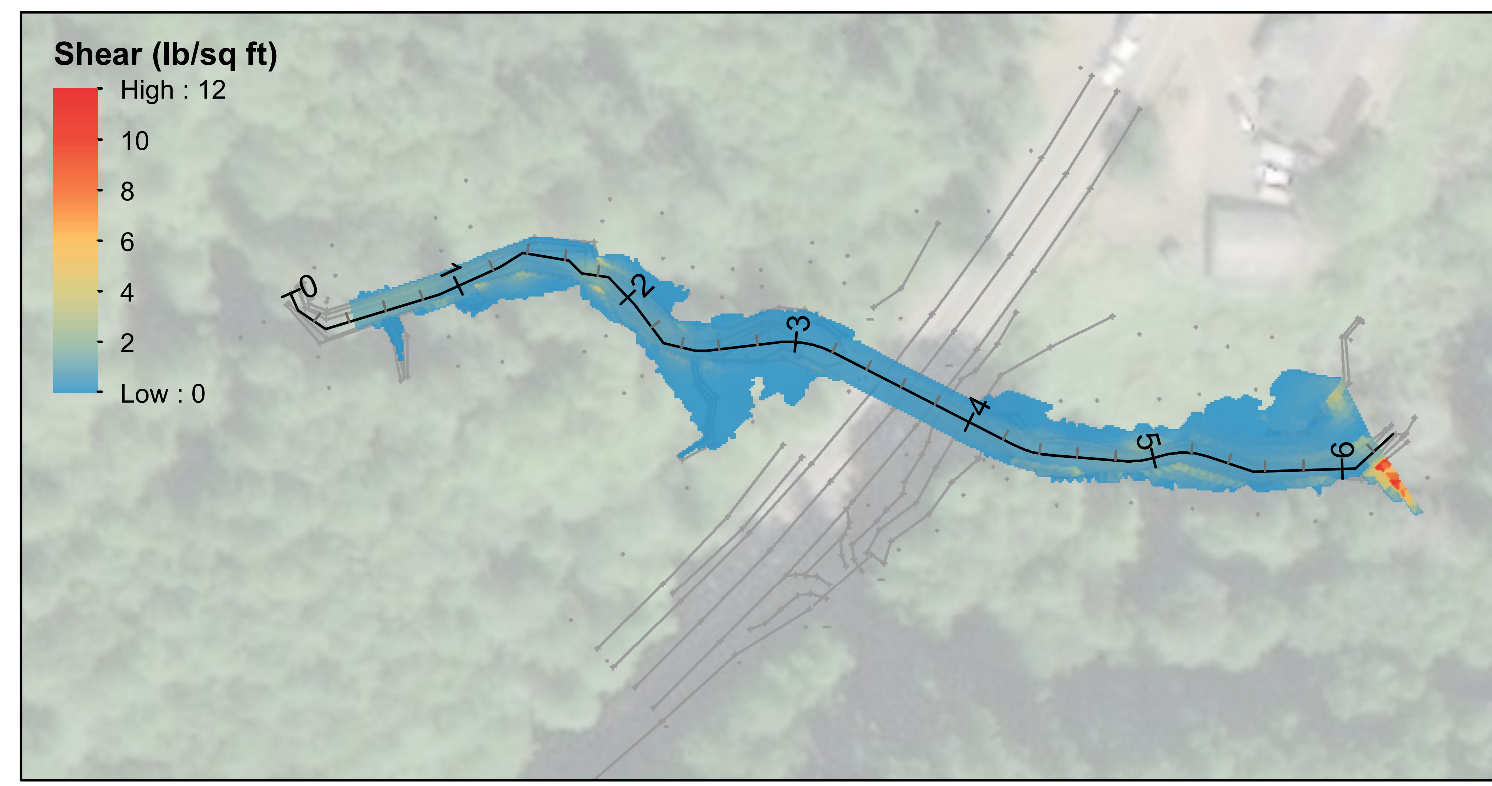
SR 108 KAMILCHE CREEK
MP 9.47



WATER SURFACE ELEVATION

DEPTH

VELOCITY



SHEAR

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0 75 150 Feet

Washington State
Department of Transportation

PROPOSED CONDITIONS - 25 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

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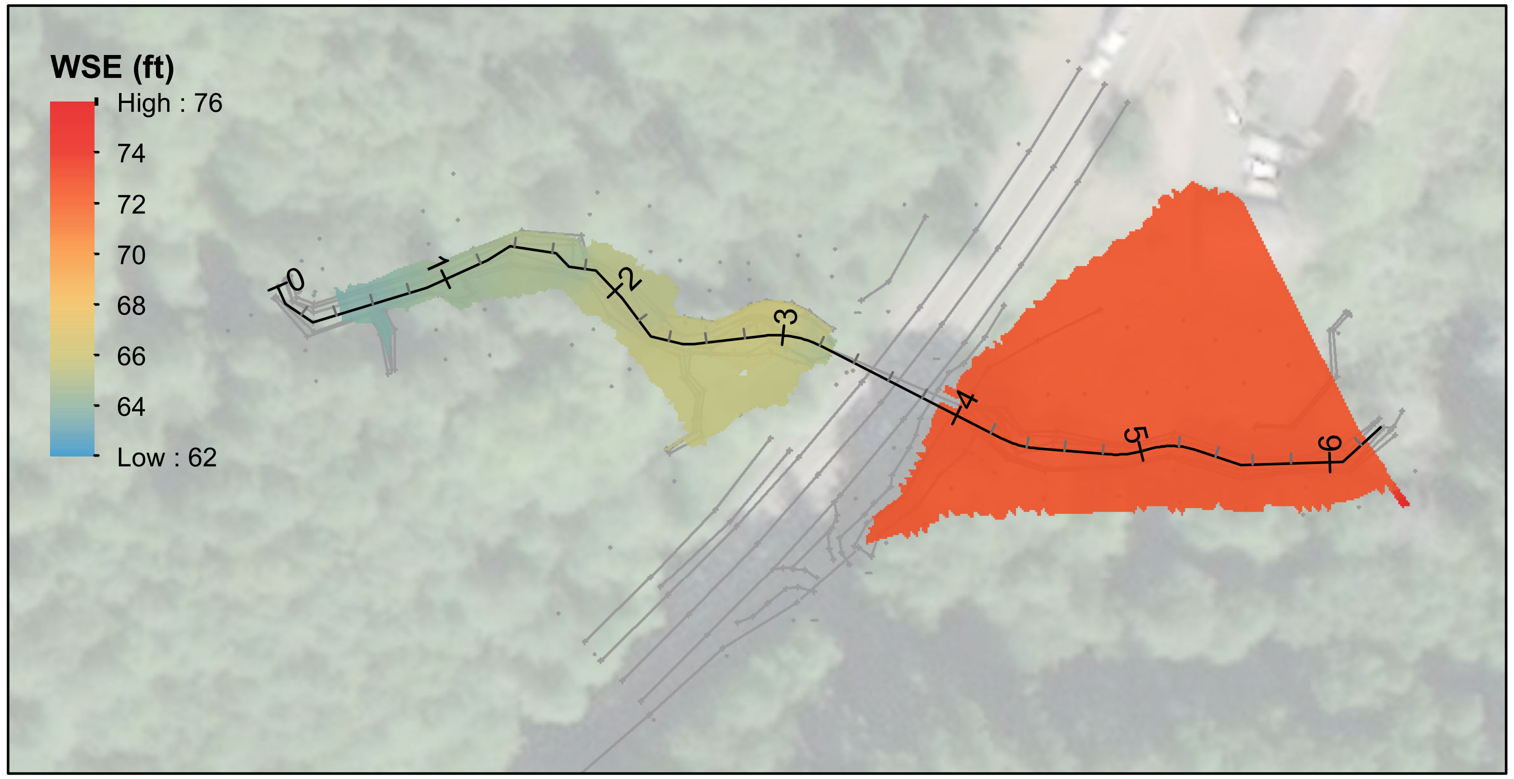

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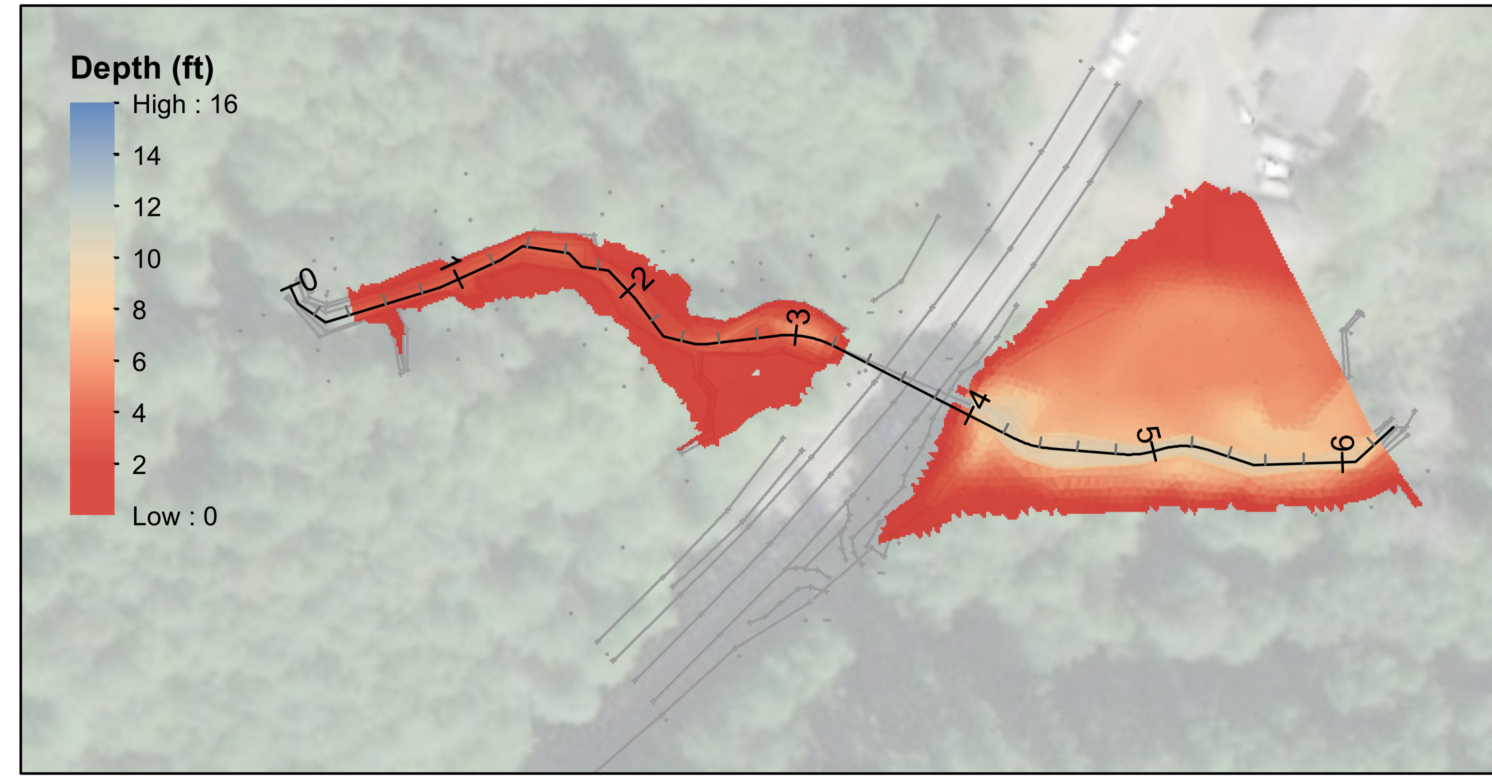
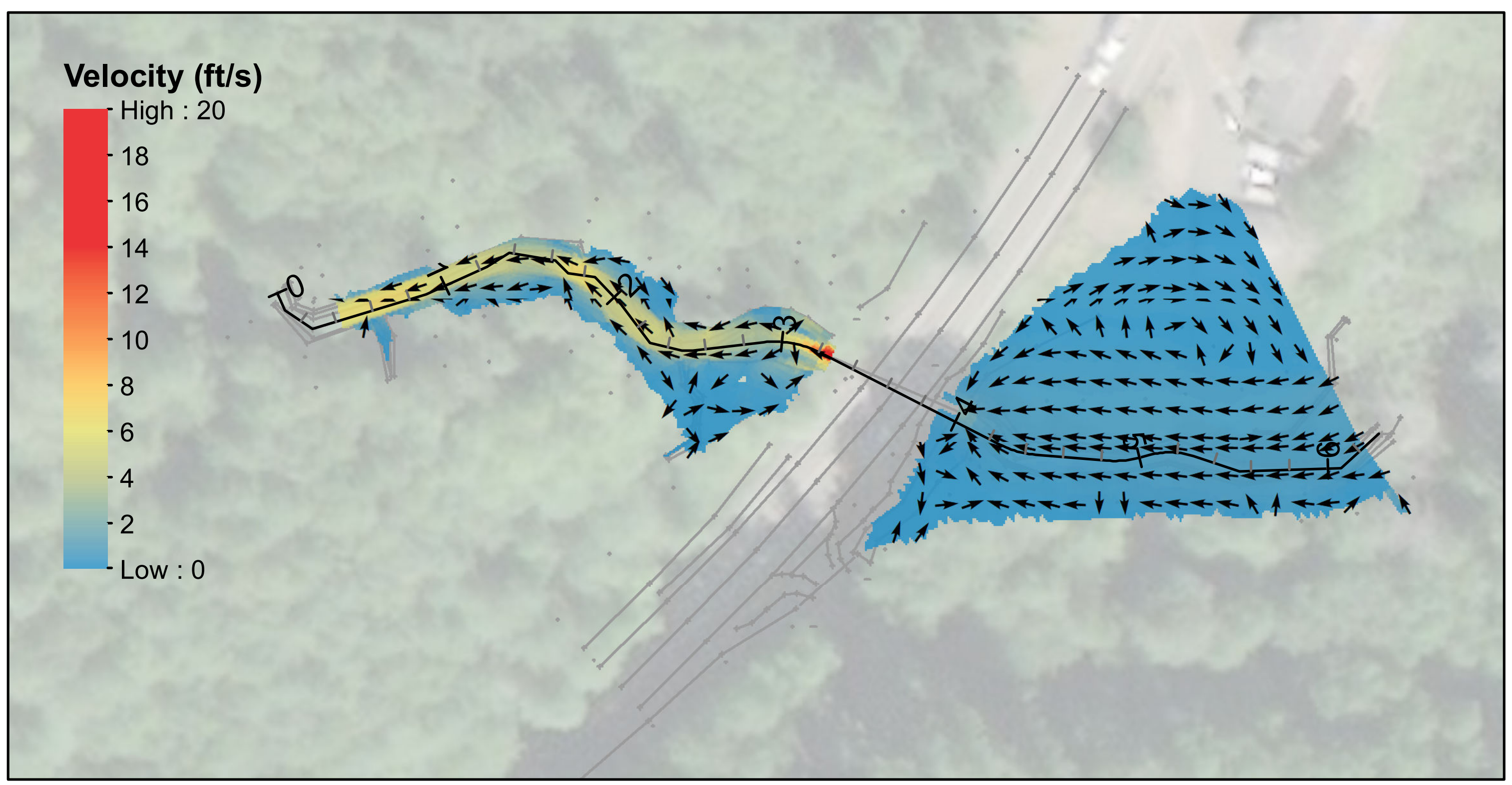


DEPTH



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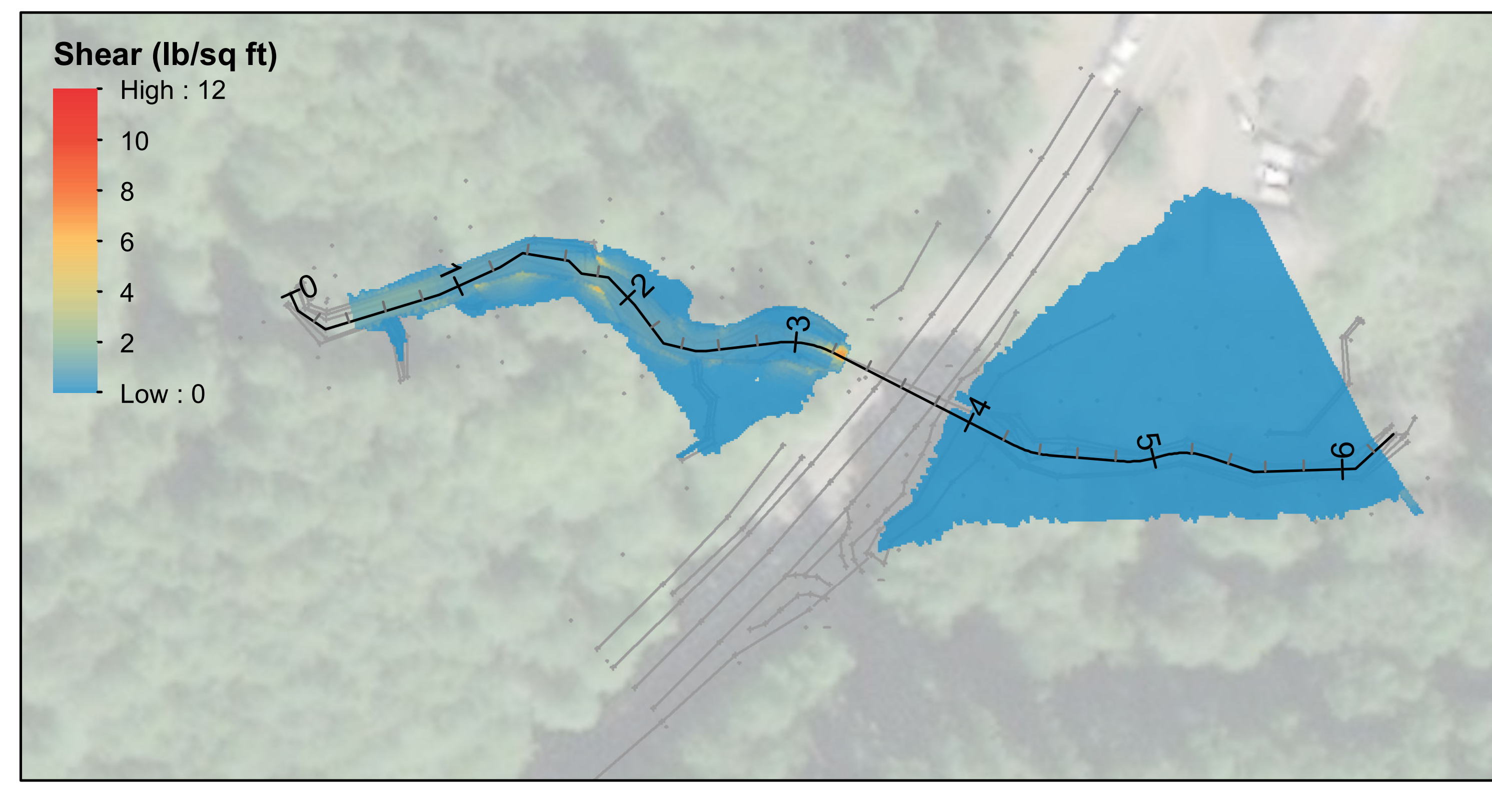


SHEAR

N

0 75 150 Feet

HDR

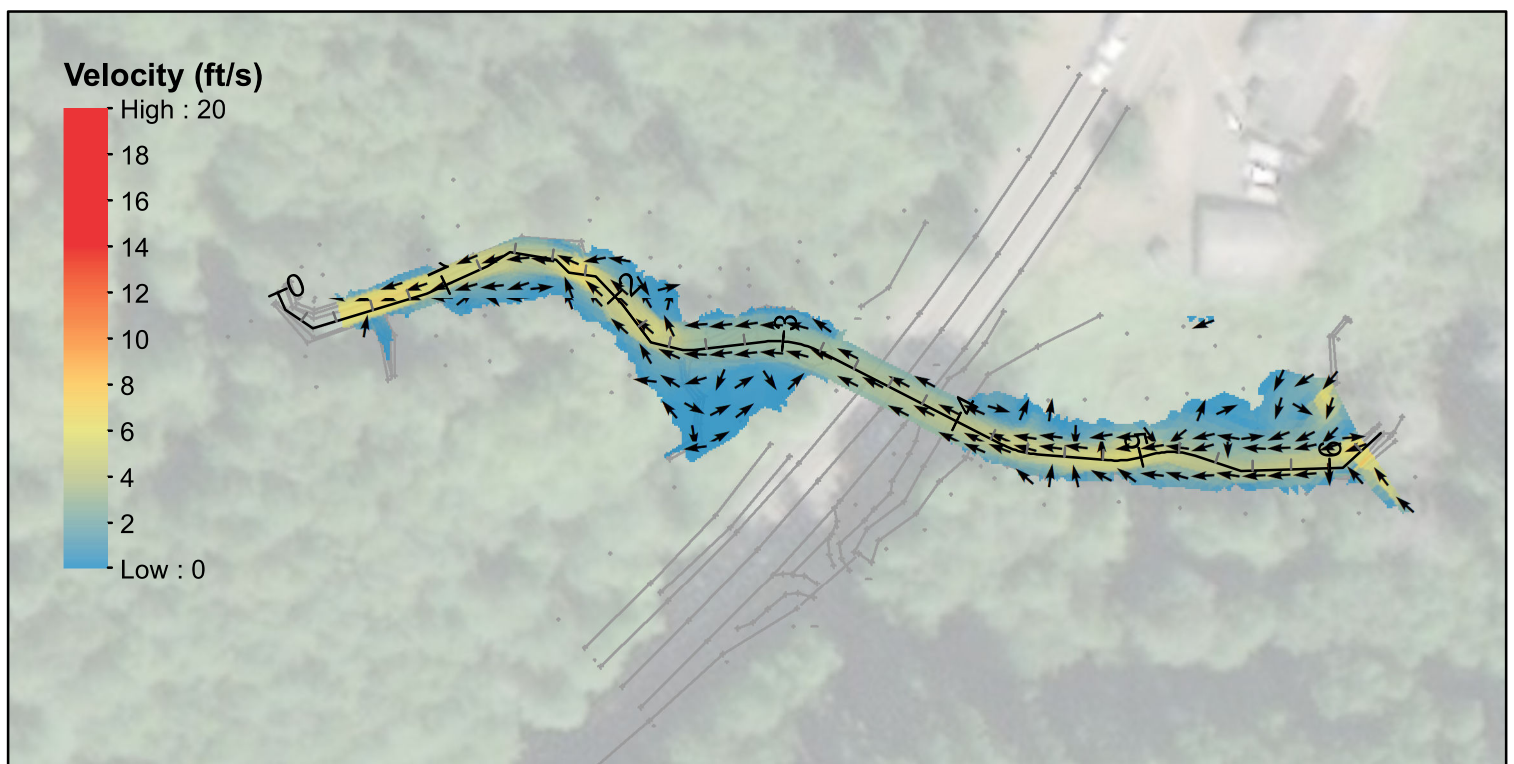
Washington State Department of Transportation

EXISTING CONDITIONS - 50 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

WATER SURFACE ELEVATION

DEPTH



VELOCITY

SHEAR

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0 75 150 Feet

FDR

Washington State Department of Transportation

PROPOSED CONDITIONS - 50 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

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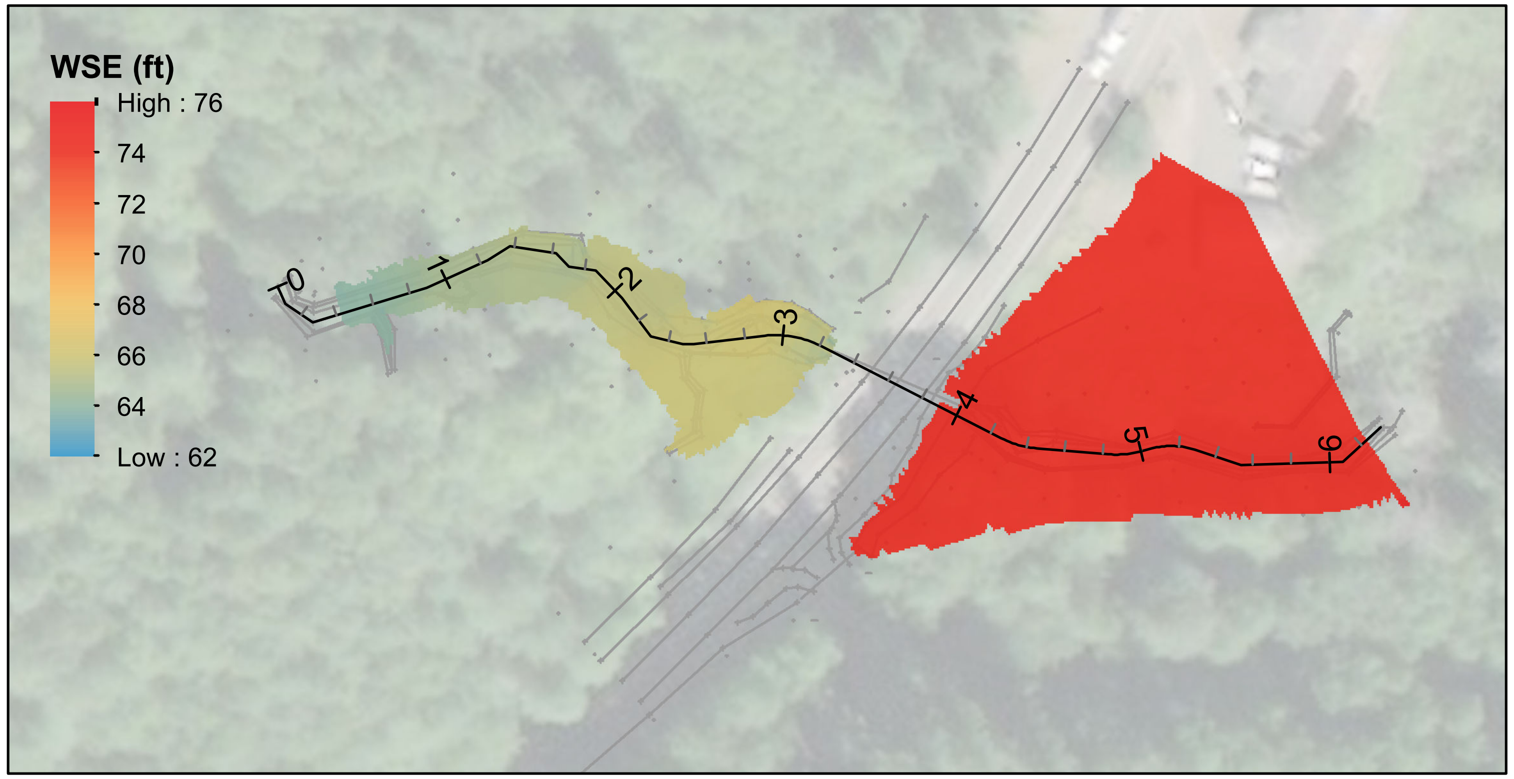
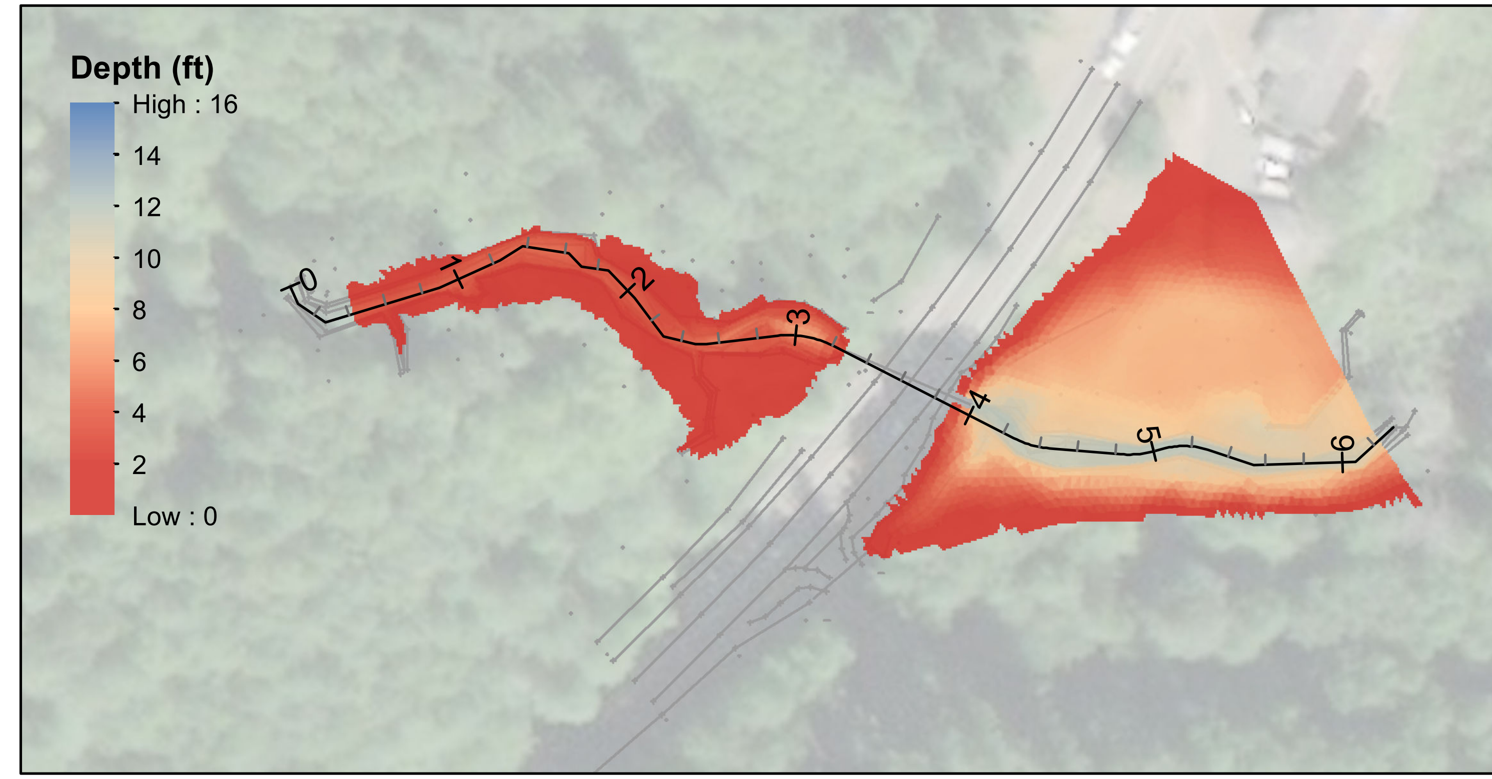


WATER SURFACE ELEVATION



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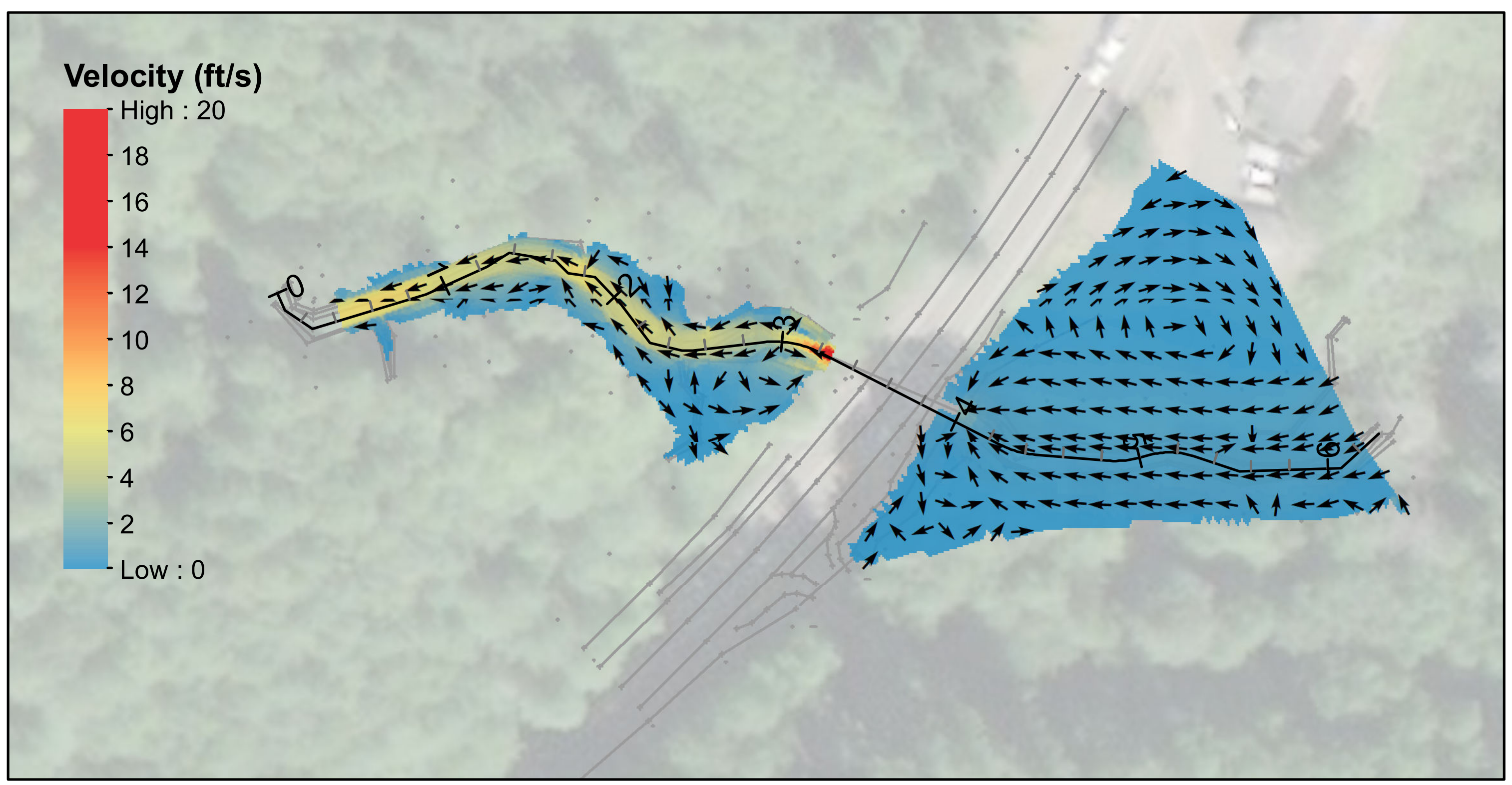

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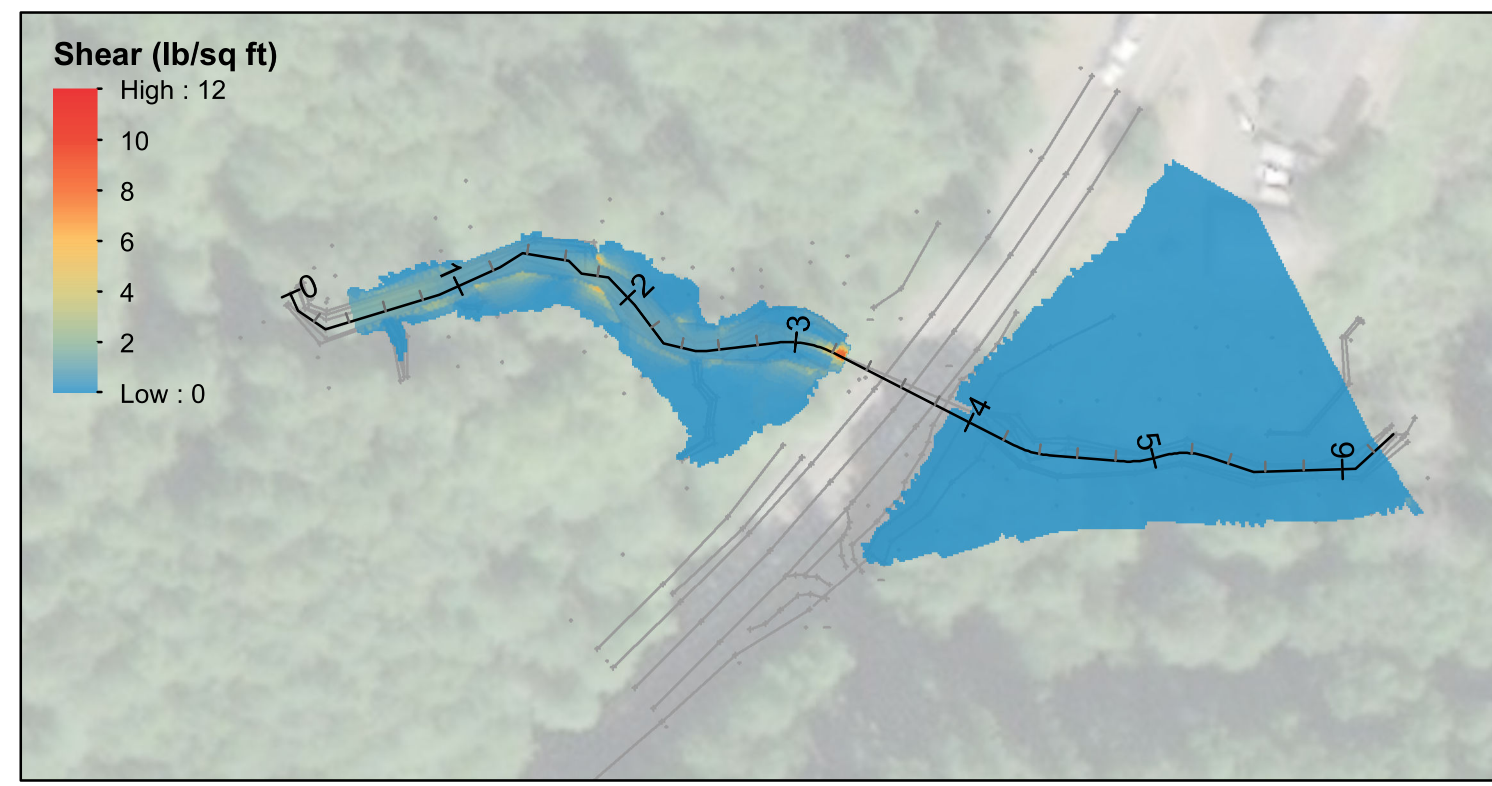

SHEAR

N

0 75 150 Feet

Washington State Department of Transportation

EXISTING CONDITIONS - 100 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

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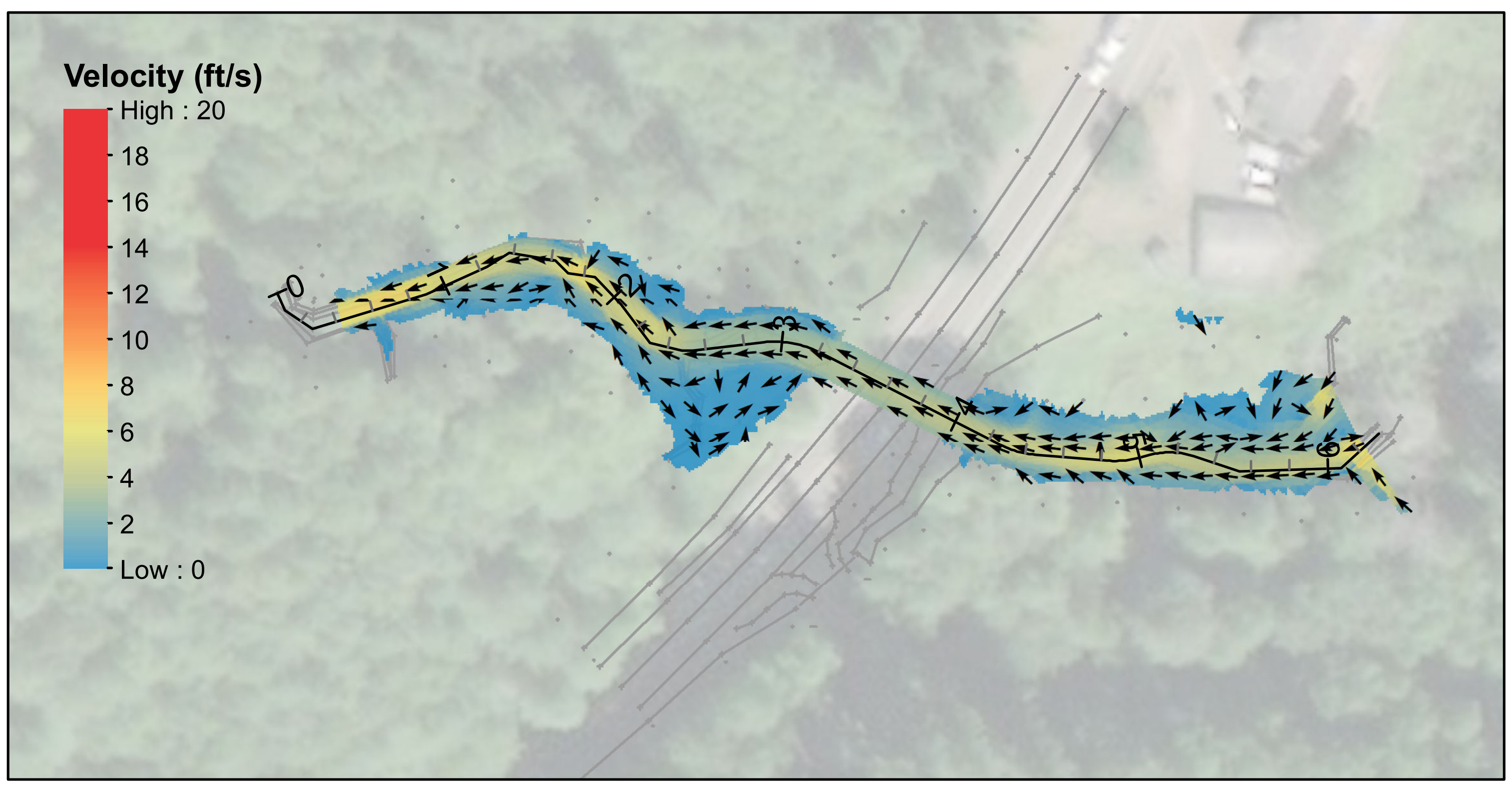
PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION

DEPTH



VELOCITY

SHEAR

N

0 75 150 Feet

HDR

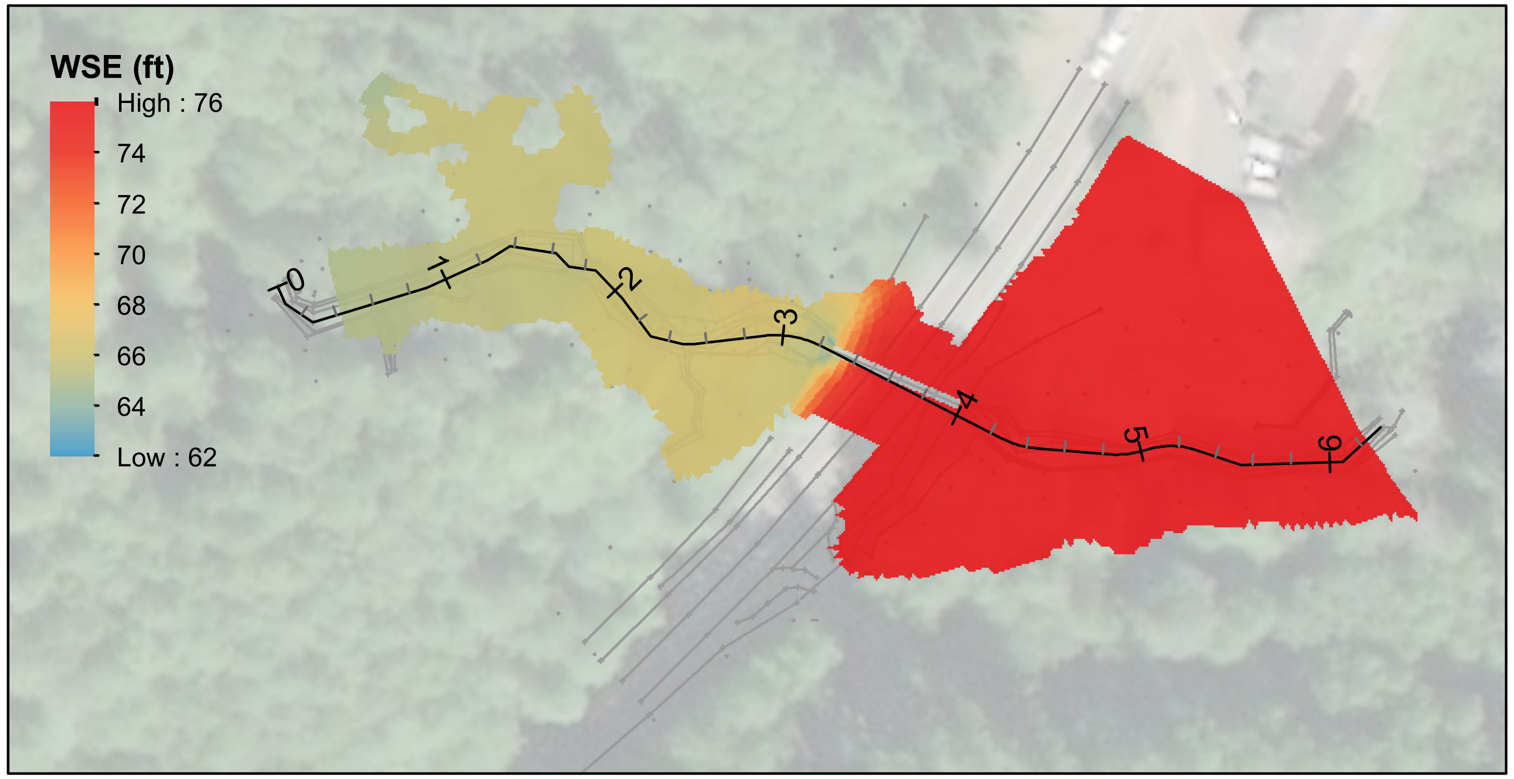
Washington State Department of Transportation

PROPOSED CONDITIONS - 100 YEAR EVENT

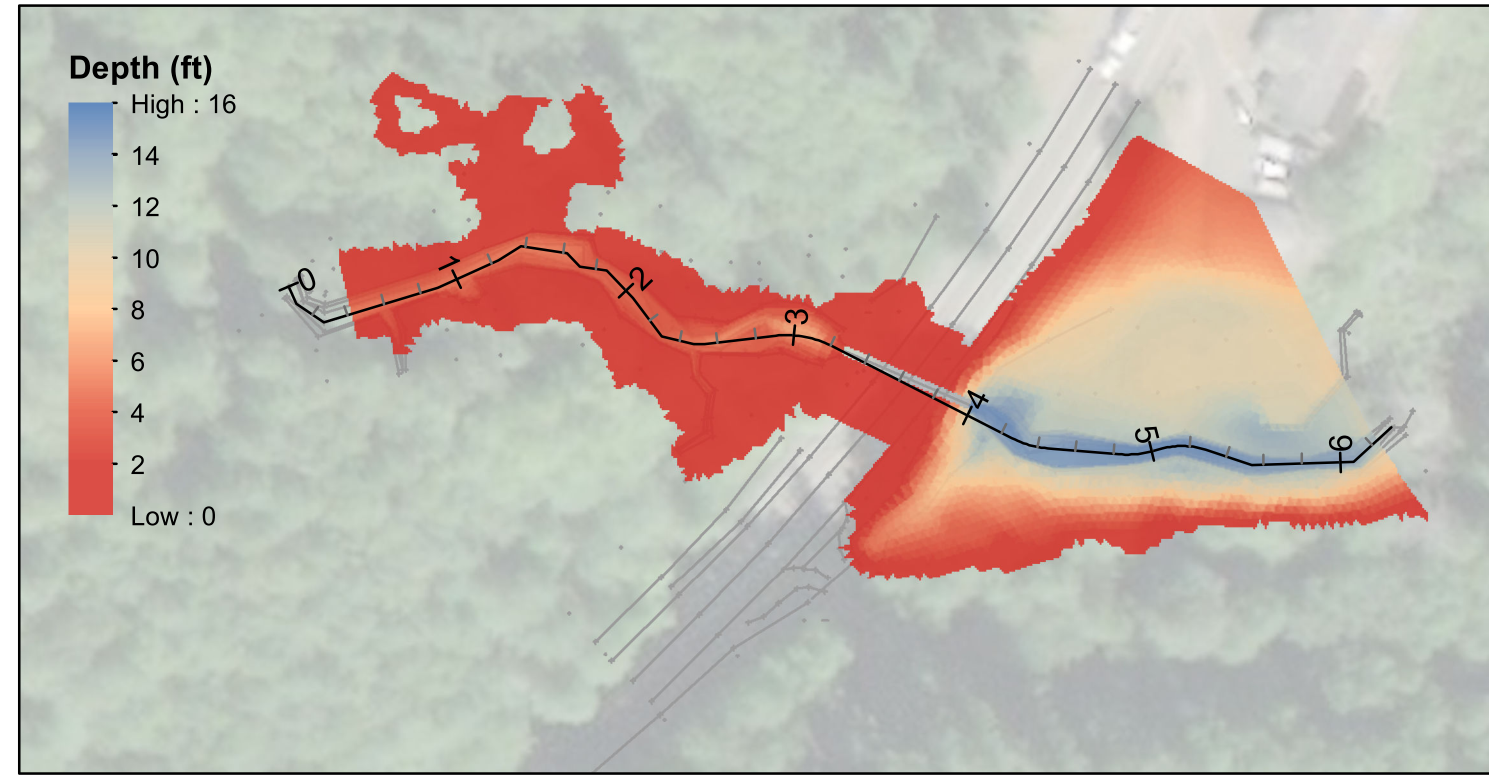
SR 108 KAMILCHE CREEK
MP 9.47

PATH: S:\SR108\MP9.47KAMILCHE\SMS\RESULTS\OUTPUT FIGURES\PROPOSED_100YR FINAL.MXD - USER: DMINNER - DATE: 10/7/2019

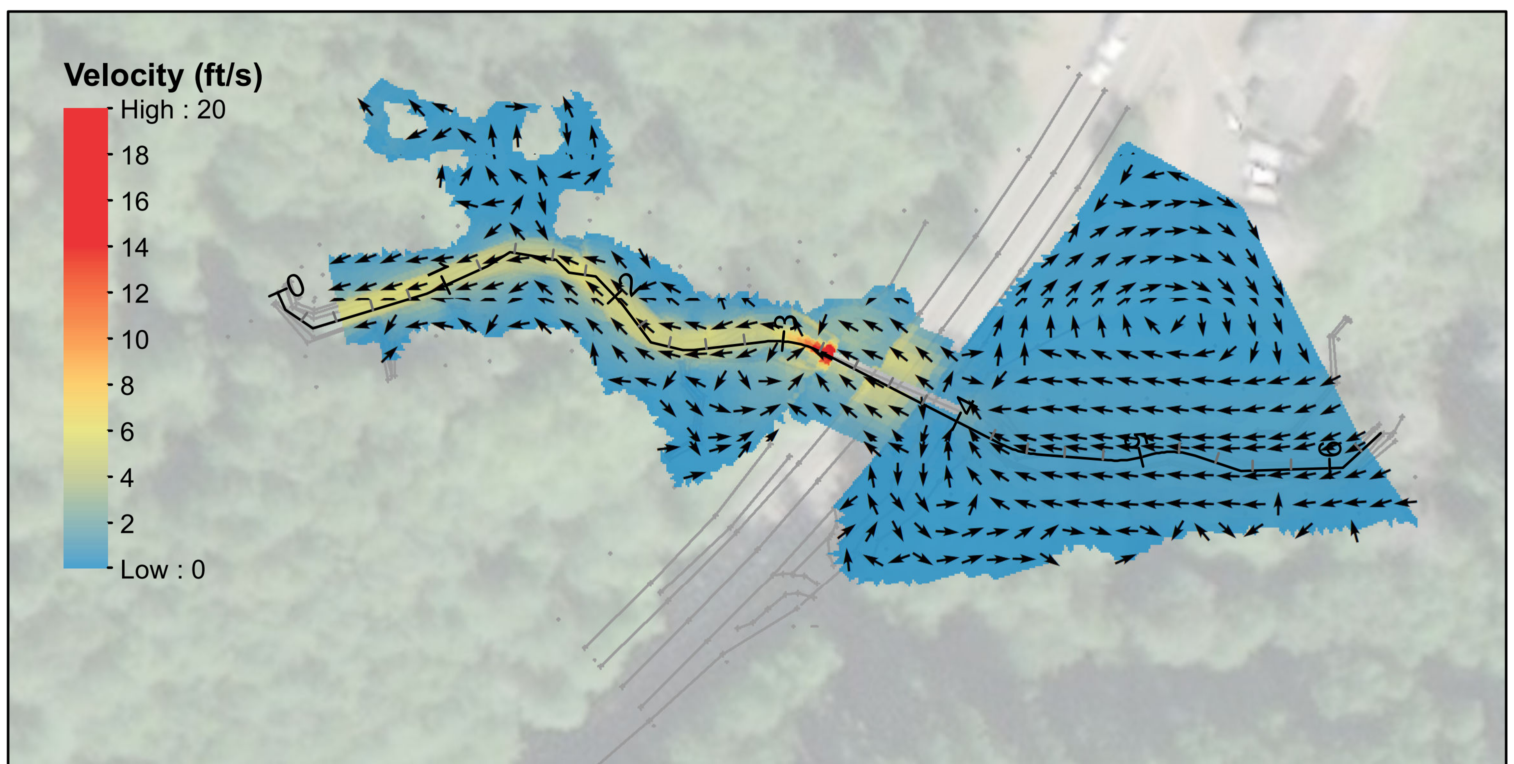
PRELIMINARY HYDARULIC DESIGN



WATER SURFACE ELEVATION



DEPTH



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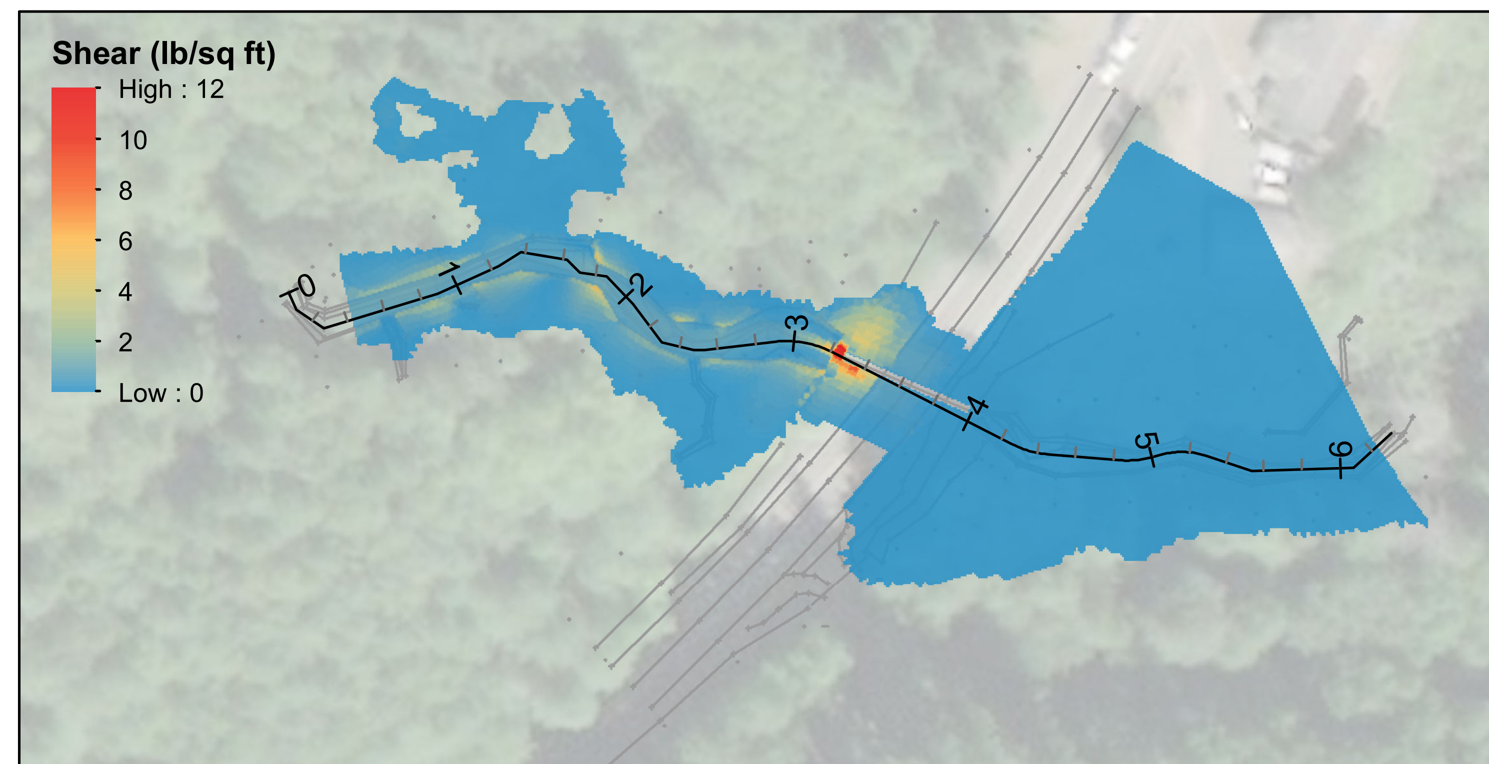

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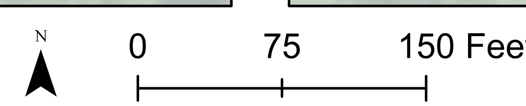


Washington State Department of Transportation

EXISTING CONDITIONS - 500 YEAR EVENT

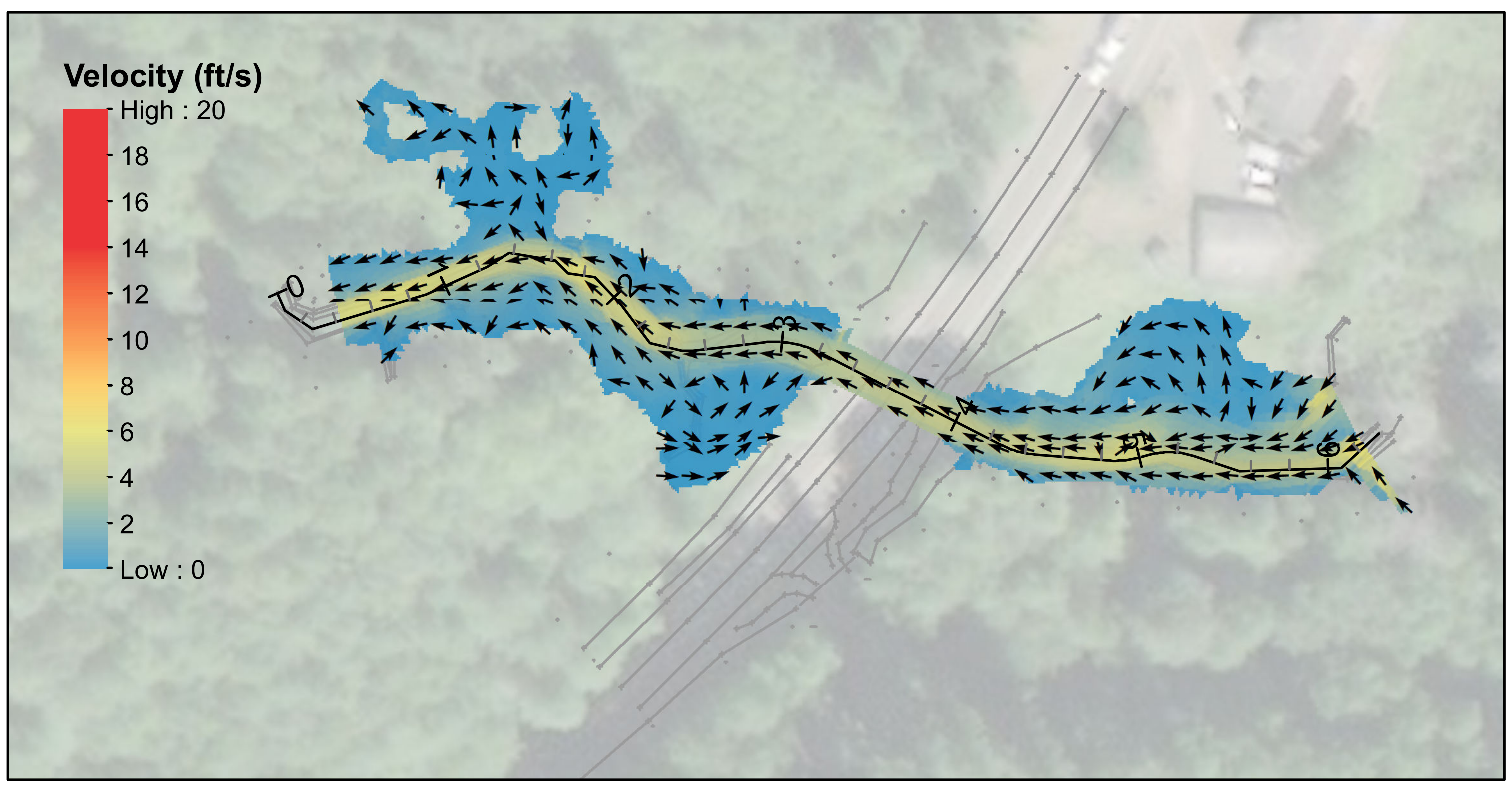
SR 108 KAMILCHE CREEK
MP 9.47

PATH: S:\SR108\MP9.47KAMILCHE\SMS\RESULTS\OUTPUT FIGURES\EXISTING_500YR FINAL.MXD - USER: DMINNER - DATE: 10/7/2019

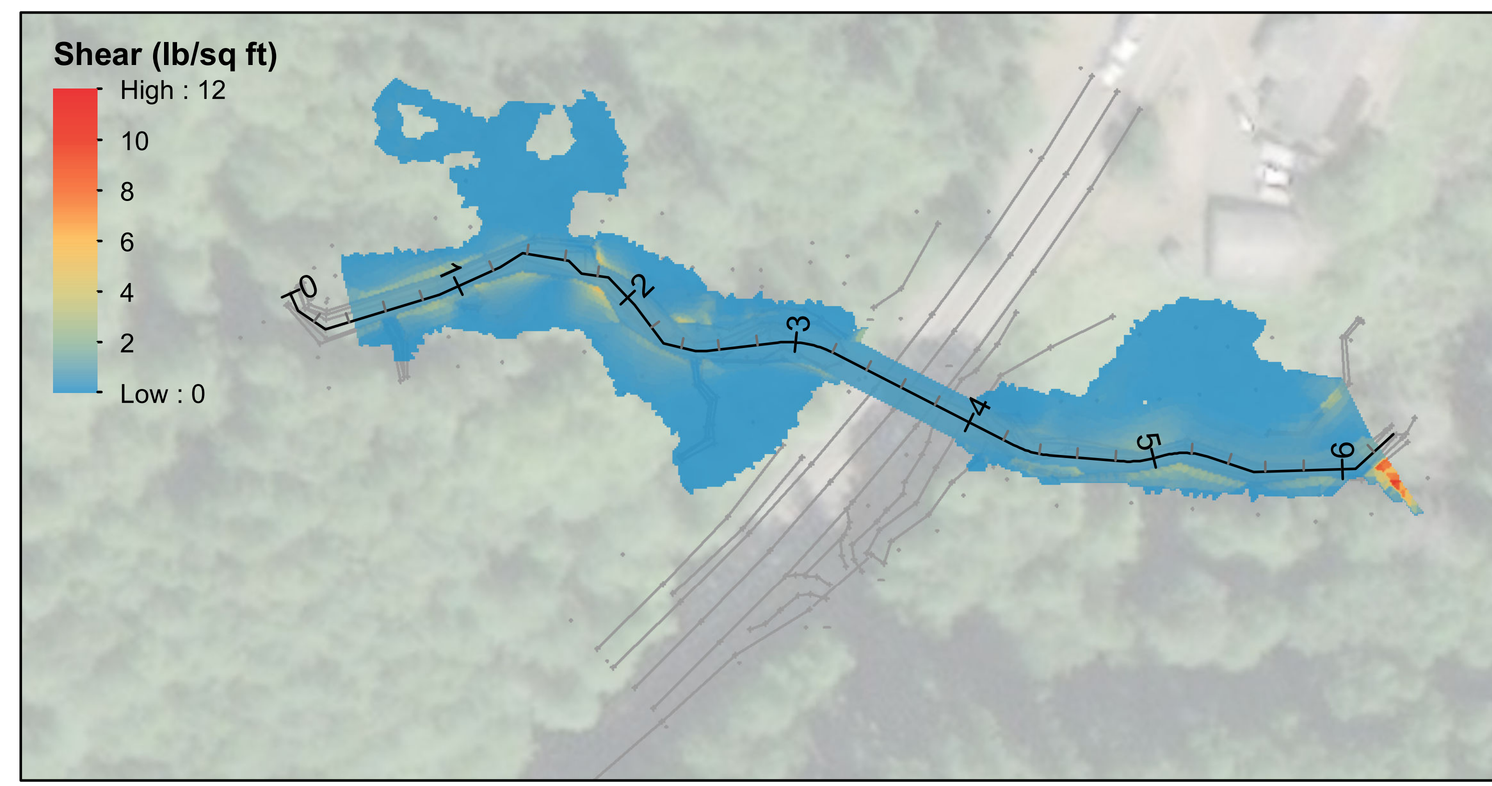
PRELIMINARY HYDARULIC DESIGN

WATER SURFACE ELEVATION

DEPTH



VELOCITY



SHEAR

N

0 75 150 Feet

HDR

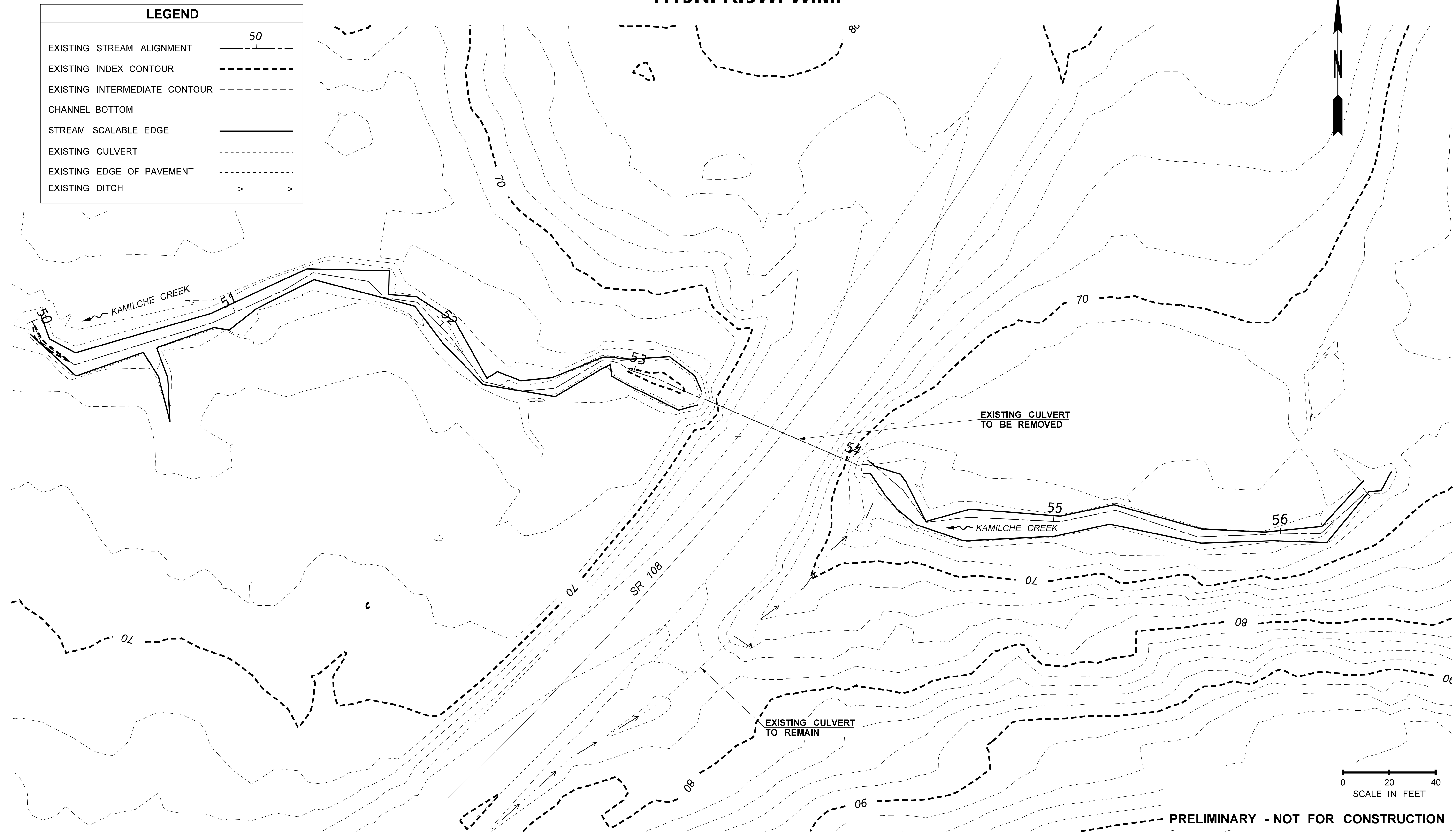
Washington State Department of Transportation

PROPOSED CONDITIONS - 500 YEAR EVENT

SR 108 KAMILCHE CREEK
MP 9.47

Appendix B – Stream Plan Sheets, Profile, Details

T.19N. R.3W. W.M.



PRELIMINARY - NOT FOR CONSTRUCTION

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TIME	3:33:26 PM
DATE	10/3/2019
PLOTTED BY	CWILCOX
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO.

LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

SR 108
MP 9.47
KAMILCHE CREEK

EXISTING STREAM PLAN

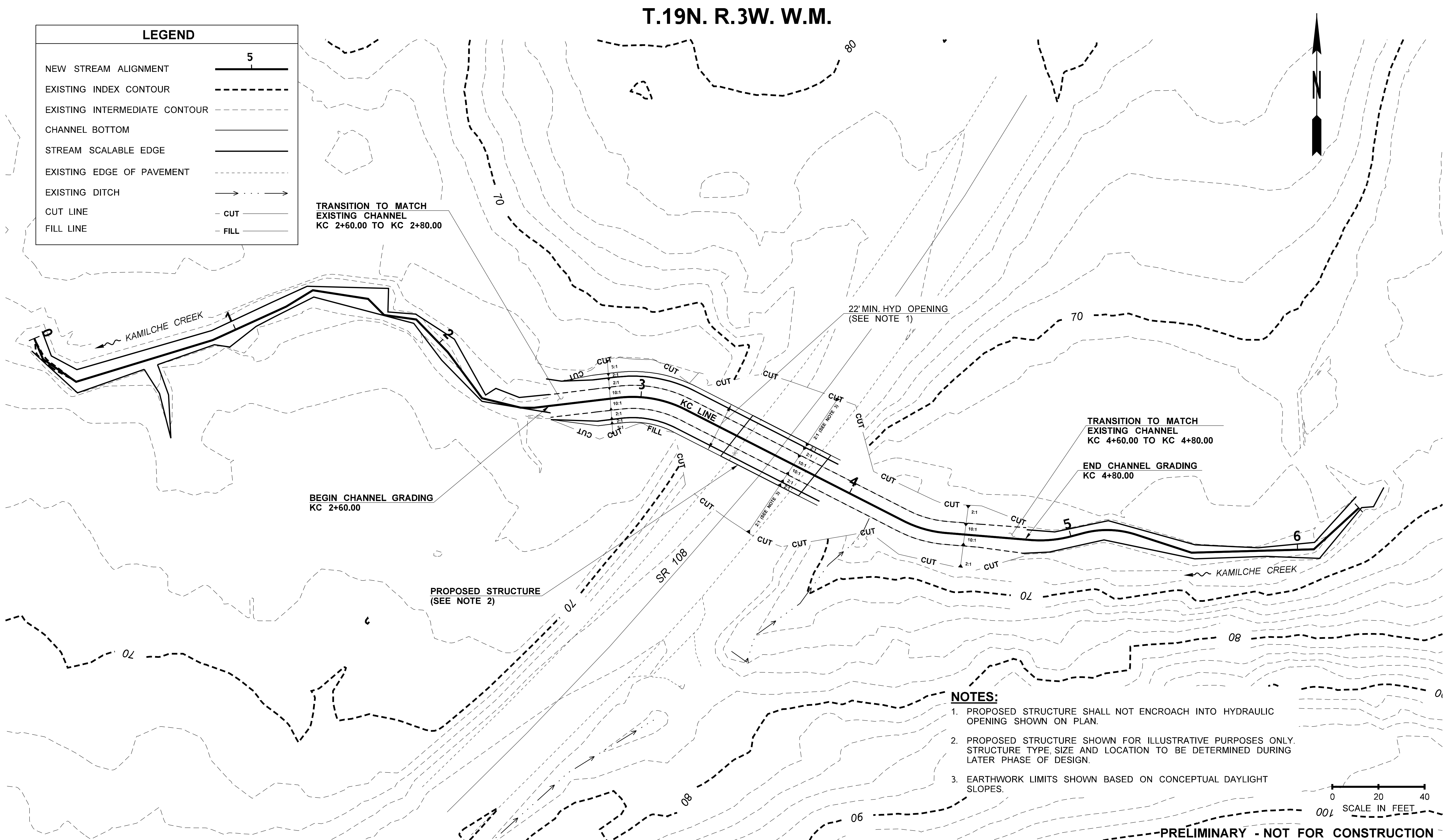
PLAN REF NO CE1

SHEET 1 OF 4 SHEETS

T.19N. R.3W. W.M.

LEGEND

NEW STREAM ALIGNMENT	5
EXISTING INDEX CONTOUR	
EXISTING INTERMEDIATE CONTOUR	
CHANNEL BOTTOM	
STREAM SCALABLE EDGE	
EXISTING EDGE OF PAVEMENT	
EXISTING DITCH	
CUT LINE	CUT
FILL LINE	FILL



NOTES:

1. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN ON PLAN.
2. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.
3. EARTHWORK LIMITS SHOWN BASED ON CONCEPTUAL DAYLIGHT SLOPES.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\9.47_KamilcheCreek\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_PS_CR_001

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TIME	8:55:40 AM
DATE	10/4/2019
PLOTTED BY	RHADDELAND
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

HDR

SR 108
MP 9.47
KAMILCHE CREEK

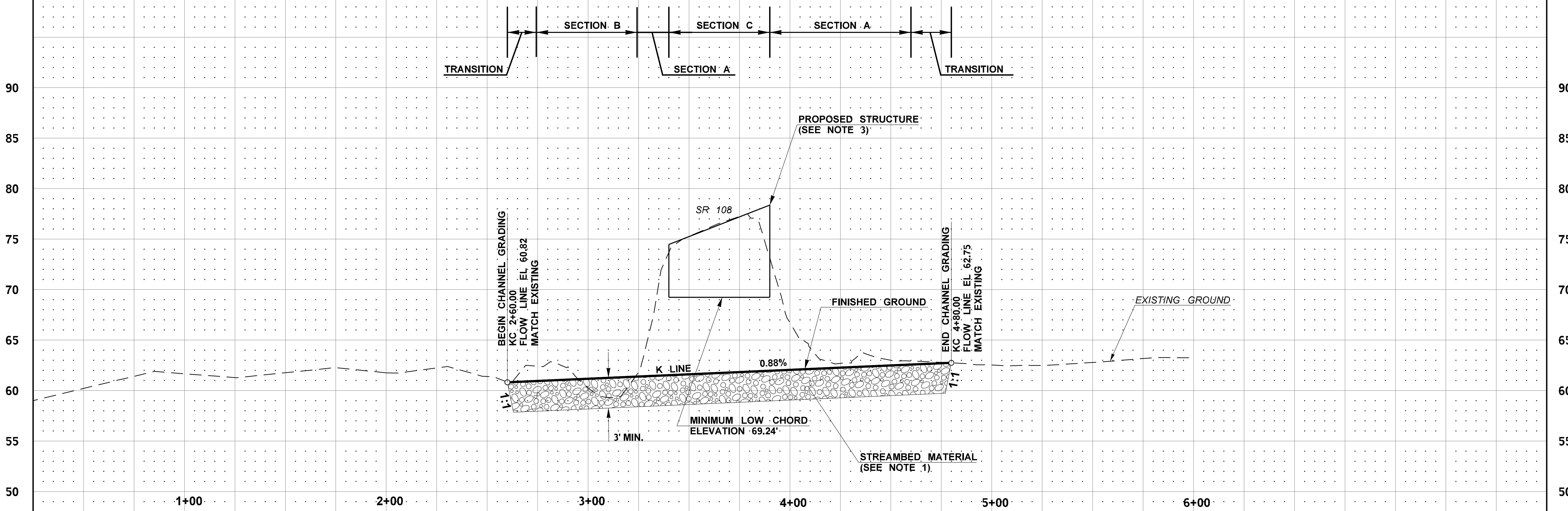
STREAM PLAN

PLAN REF NO CR1

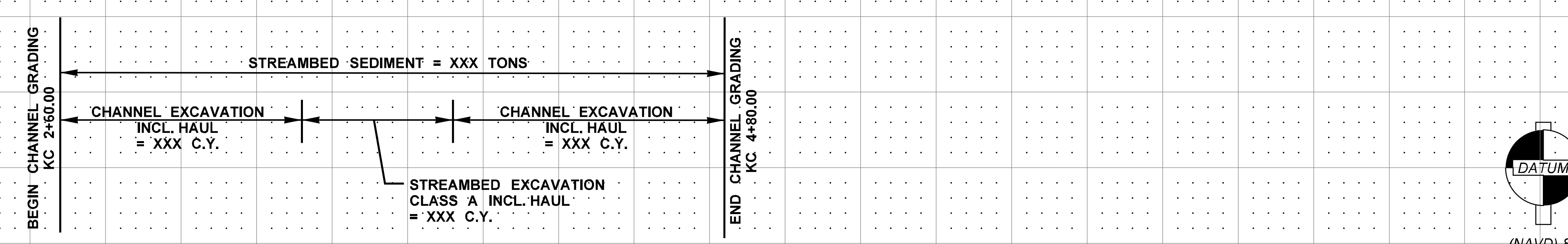
SHEET 2 OF 4 SHEETS

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES FOR STREAMBED MATERIALS.
2. SEE SHEET CD1 FOR STREAM SECTIONS.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.



KC LINE PROFILE



PRELIMINARY - NOT FOR CONSTRUCTION

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DATE	10/4/2019
PLOTTED BY	RHADDELAND
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION | DATE | BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	

JOB NUMBER: XXXXX

CONTRACT NO.

LOCATION NO. XL5950

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

HDR

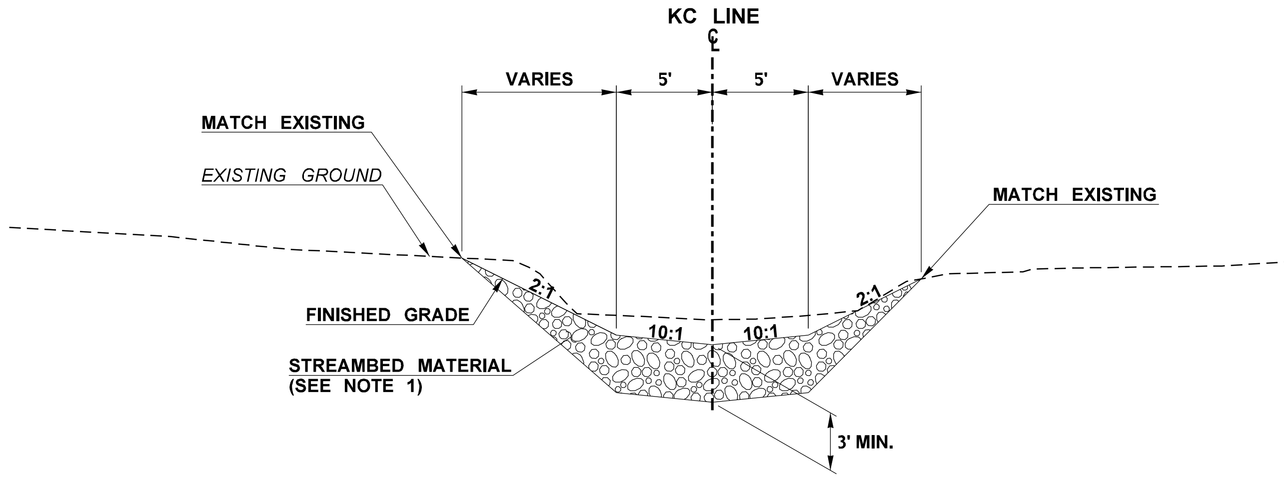
SR 108
MP 9.47
KAMILCHE CREEK

STREAM PROFILE

PLAN REF. NO. CP1

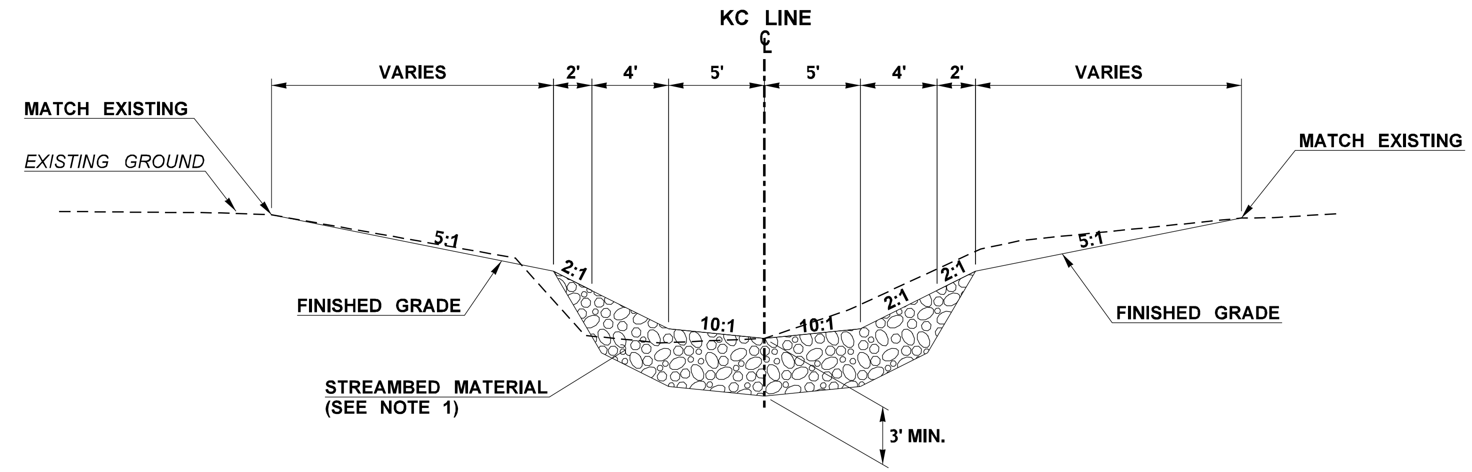
SHEET 3 OF 4 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\9.47_KamilcheCreek\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_PS_PR_CP_001



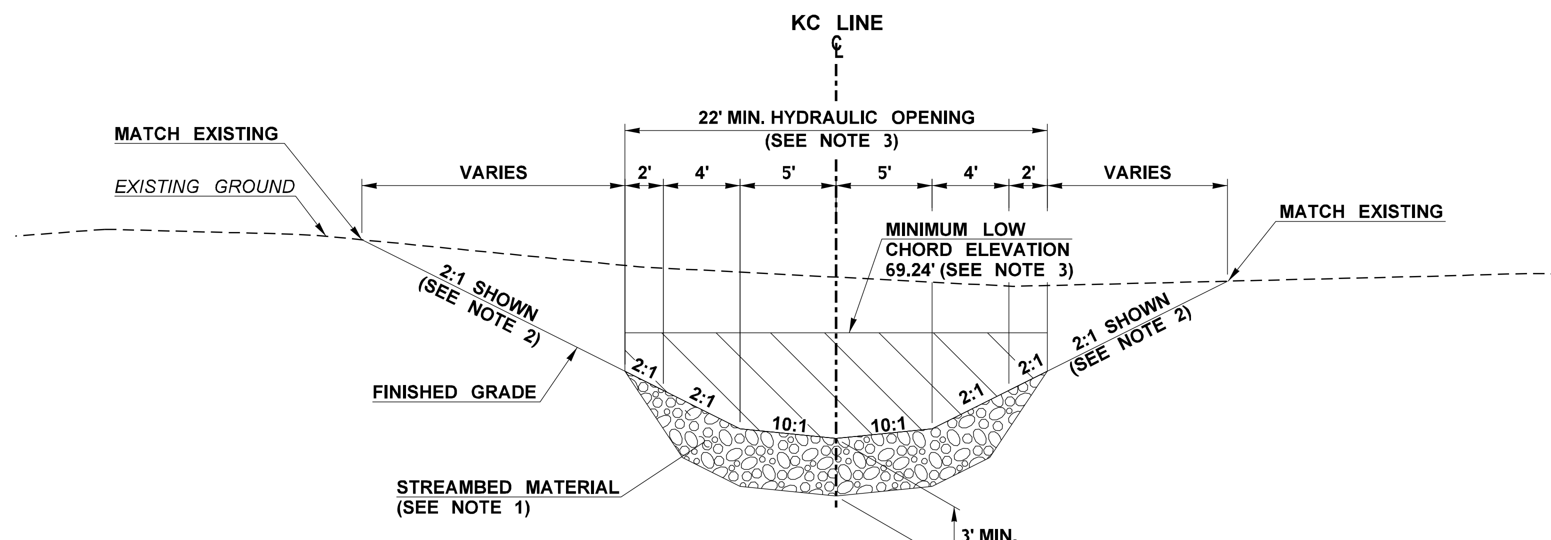
SECTION A

STATION
KC 3+24.00 TO 3+40.00
KC 3+90.00 TO 4+60.00



SECTION B

STATION
KC 2+80.00 TO 3+24.00



SECTION C

STATION
KC 3+40.00 TO 3+90.00

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.

PRELIMINARY - NOT FOR CONSTRUCTION

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\9.47_KamilcheCreek\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_DE_CD_001

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TIME	10:24:52 PM
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PLOTTED BY	CWILCOX
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

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MP 9.47
KAMILCHE CREEK

STREAM DETAILS

PLAN REF NO CD1

SHEET 4 OF 4 SHEETS

Appendix C – WDFW Future Projections for Climate-Adapted Culvert Design Printout

Future Projections for Climate-Adapted Culvert Design

Project Name: 997225

Stream Name:

Drainage Area: 281 ac

Projected mean percent change in bankfull flow:

2040s: 14.6%

2080s: 20.8%

Projected mean percent change in bankfull width:

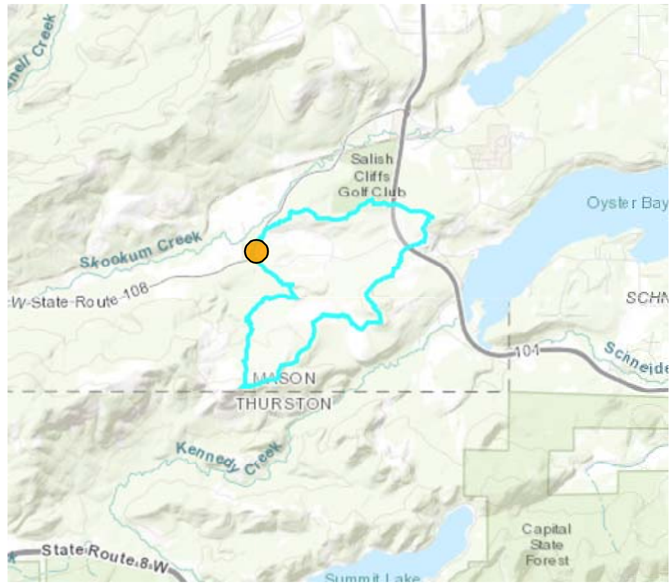
2040s: 7.1%

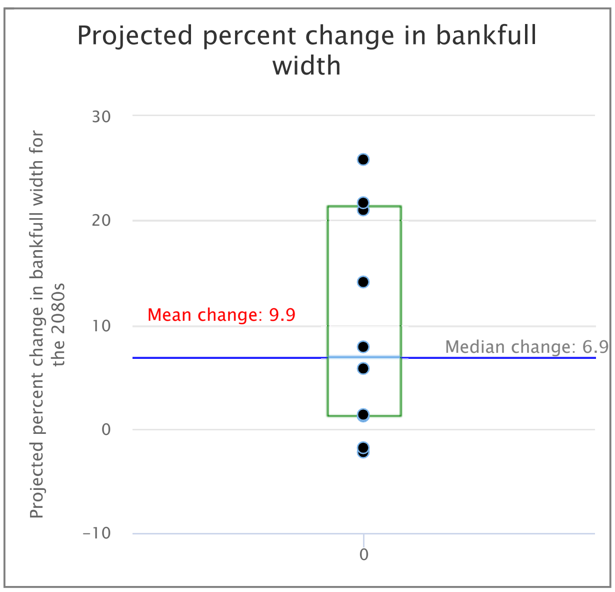
2080s: 9.9%

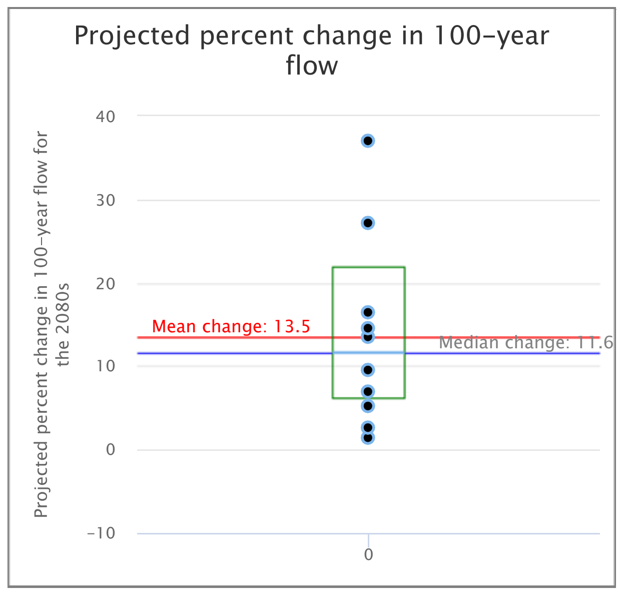
Projected mean percent change in 100-year flood:

2040s: 7.5%

2080s: 13.5%







Black dots are projections from 10 separate models